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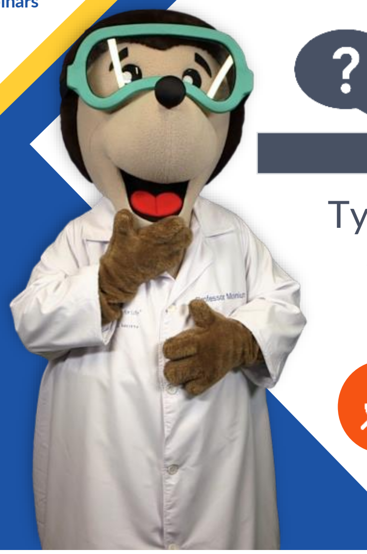

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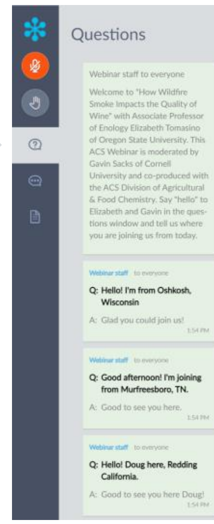

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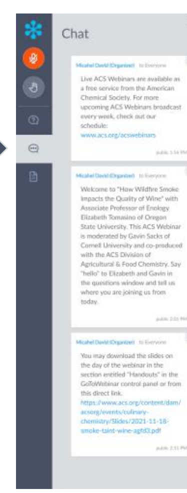
Announcements and hyperlinks from our team



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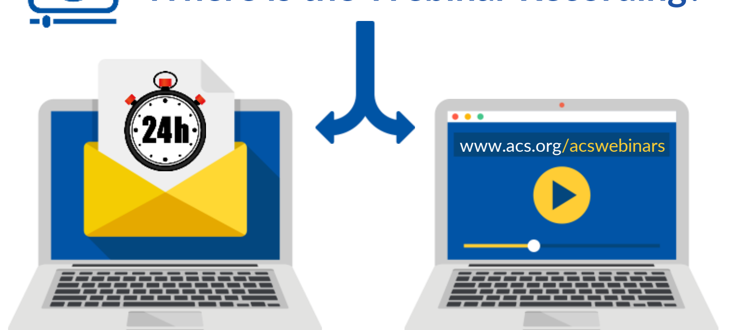

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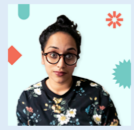
Sam Jones, PhD
Science Writer & Exec Producer



Deboki Chakravarti, PhD
Science Writer & Co-Host

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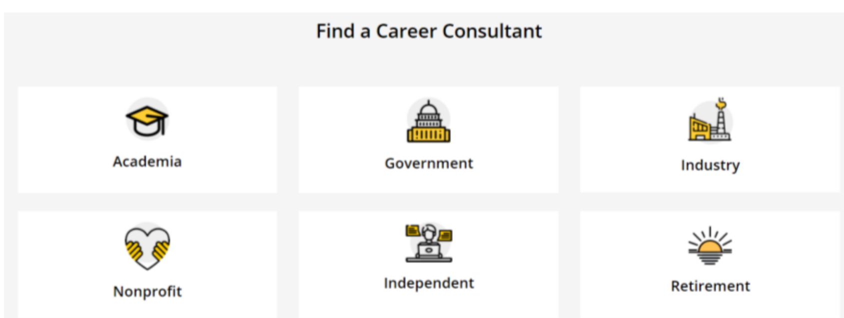

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ACS Scholar Adunoluwa Obisesan

BS, Massachusetts Institute of Technology, June 2021
(Chemical-biological Engineering, Computer Science & Molecular Biology)

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https://fs7.formsite.com/acsdiversity/ACSMemberFeedback/index.html

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ACS Career Resources

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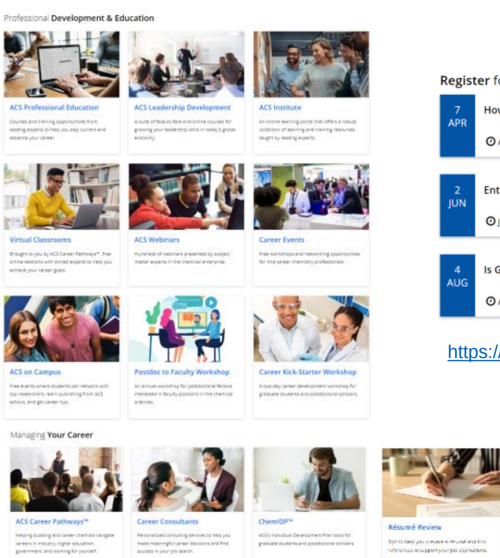

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- 5 MAY — Careers in Government — May 5, 2022
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- 7 JUL — Networking — July 7, 2022
- 4 AUG — Is Grad School Right for Me? — August 4, 2022
- 1 SEP — Leadership and Soft Skills Development – What You Need to Advance in Your Career — September 1, 2022

https://www.acs.org/content/acs/en/careers/personal-career-consulting.html

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Thurs., May 5, 2022 | 2:00pm–3:30pm ET

Role of Polymer Science in Water Purification Membranes

Co-produced with the ACS Division of Polymer Chemistry

Wed., May 11, 2022 | 2:00pm–3:00pm ET

Adapting to Climate Change: Insights from Indigenous Peoples

Co-produced with ACS Policy and the American Association for the Advancement of Science

Thurs., May 12, 2022 | 2:00pm–3:00pm ET

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The Research Landscape for Green Energy:
From Hydrogen Fuel to Solar Cells and Beyond
LEILANI LOTTI DIAZ
Information Scientist, CAS
YIYING WU
Leet Professor, The Ohio State University
DHARIK MALLAPRAGADA
Research Scientist, MIT Energy Initiative
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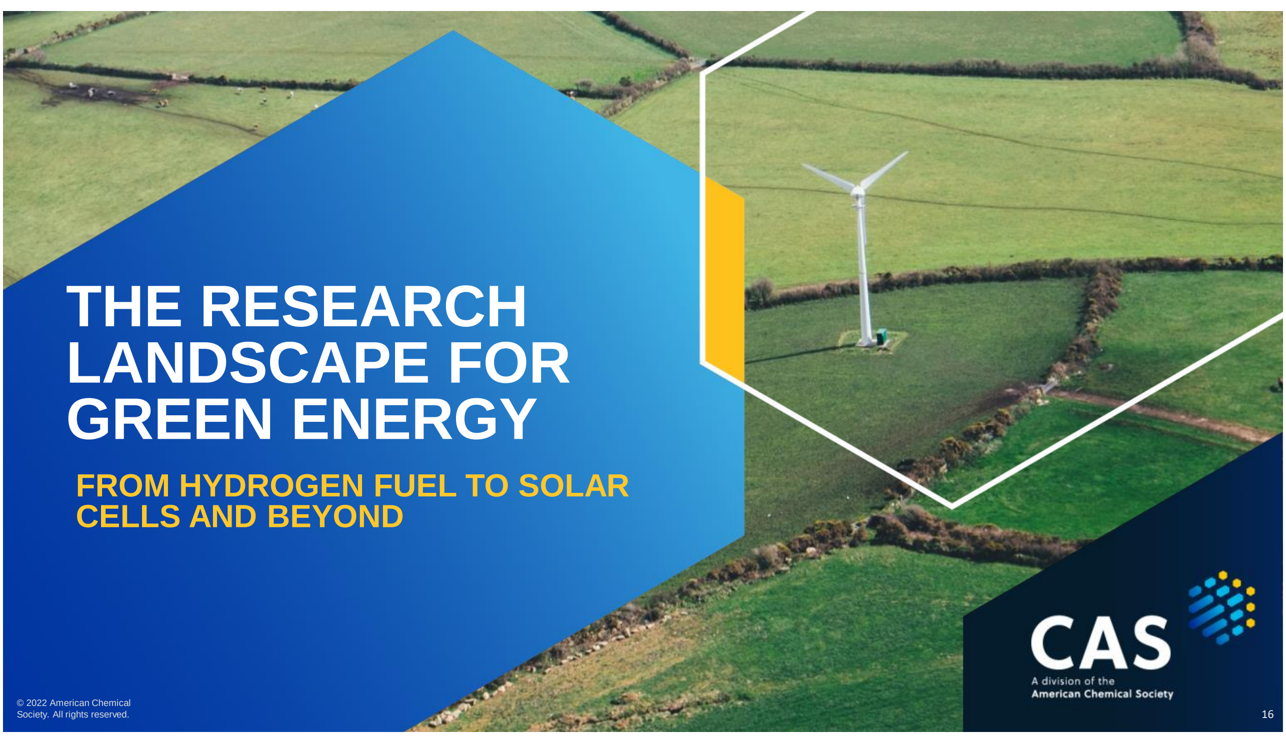
THE RESEARCH LANDSCAPE FOR GREEN ENERGY
FROM HYDROGEN FUEL TO SOLAR CELLS AND BEYOND
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CAS connects the world's science

At CAS, our passion is advancing scientific progress.

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BETWEEN PROBLEMS AND PROGRESS
ARE CONNECTIONS THAT MATTER

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Expert Panelists & Moderator

Leilani Lotti Diaz
Information Scientist,
CAS

Yiying Wu
Leet Professor, The
Ohio State University

Dharik Mallapragada
Research Scientist,
MIT Energy Initiative

Gilles Georges
Chief Scientific Officer,
CAS

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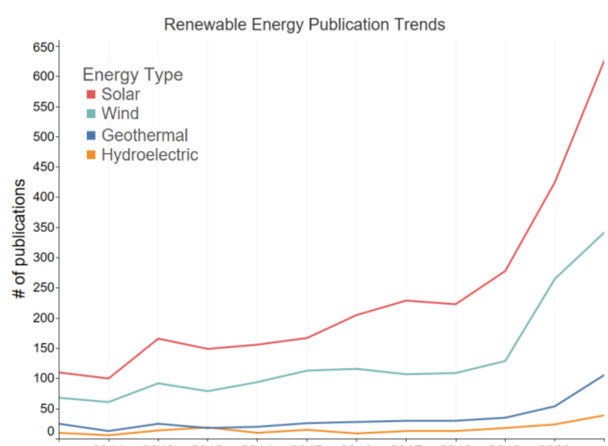
Green energy technologies

Why we need them and renewable energy trends

- Dependence on fossil fuels
  - Climate change
    - CO_2 emissions
  - Pollution/ecological consequences
    - SO_2, NO_x, soot
  - Finite resource
  - Energy dependence on foreign resources



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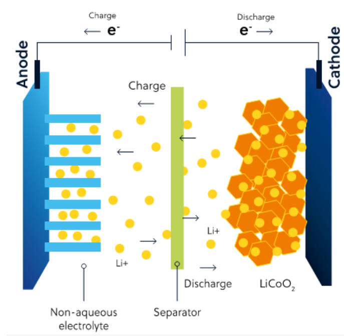
Energy Carriers

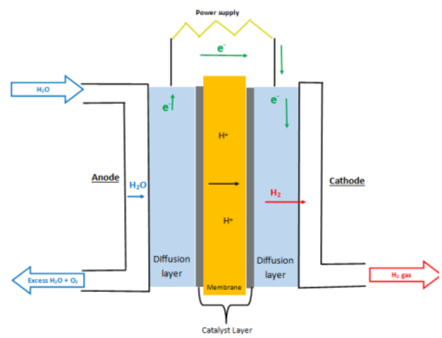
Solution for fluctuation and portability of renewables

- Are a fuel or system
- Store energy for future use
- Examples:
  - Fossil fuels
  - Batteries
  - Hydrogen

Lithium-ion batteries



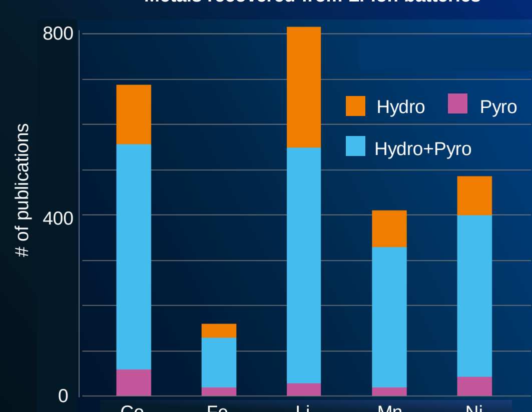
Green Hydrogen



LIB recycling is a challenge

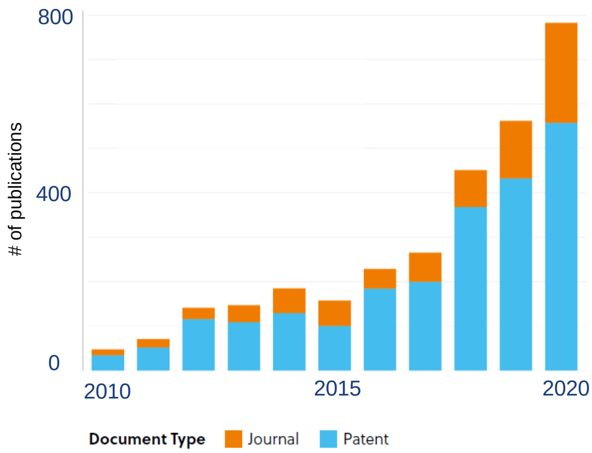
With high growth in hydrometallurgy and pyrometallurgy

Metals recovered from Li-ion batteries



Recycling of LIBs high commercial value

China and patent publications are leading the way driven by the future potential



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Green hydrogen has different challenges

Driven by lack of infrastructure

Production

Cost of Catalysts (Pt, Pd)

Hydrogen Evolution Reaction

Storage

Safety

Costs

Transportation

Materials Based

Fuel Cell Utilization

Cost of Catalysts

Oxygen Reduction Reaction

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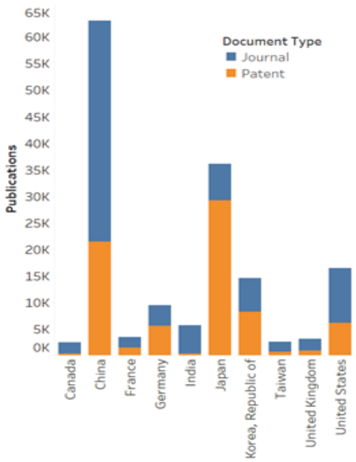
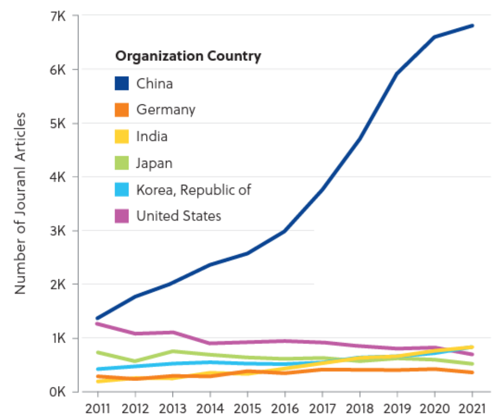
China leads green hydrogen publications

Japan in 2nd place and the US comes in 3rd

Publications by Country



Publication Trends by Country



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Audience Survey Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT

Among the three research topics listed below, which one do you think need more research attention than what it has currently?

- Hydrogen production
- Hydrogen storage
- Hydrogen fuel cells
- Not sure
- Other (Let us know more in the chat!)

** If your answer differs greatly from the choices above tell us in the chat!*

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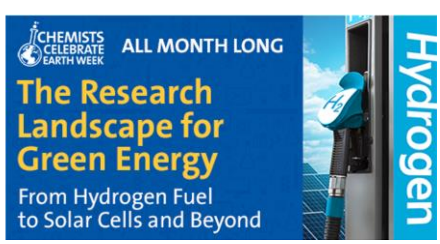
Solar Cell and Rechargeable Battery Technologies

Yiying Wu, Ph.D

Department of Chemistry & Biochemistry
The Ohio State University
Columbus, Ohio



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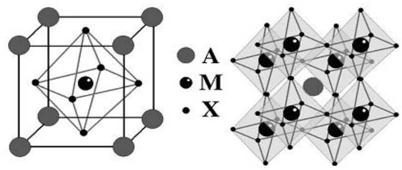
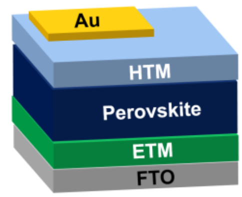
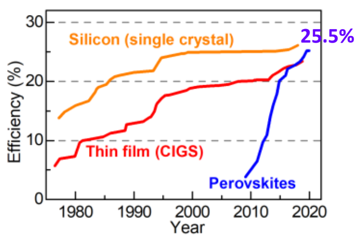
Organic-Inorganic Hybrid Perovskite Solar Cells (PSCs)



A: Organic cation, such as $CH_3NH_3^+$
M: Metal ion, such as Pb^{2+}
X: Halogen ion, such as I^-



Hole transport material (HTM)
Electron transport material (ETM)



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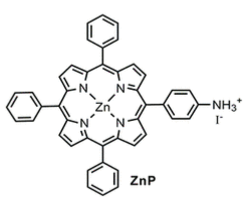
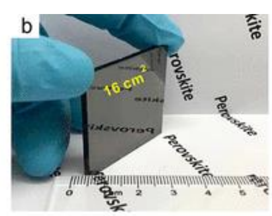
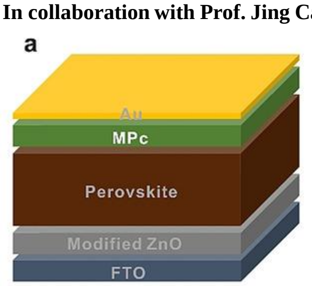
Large area processing & hole transporting

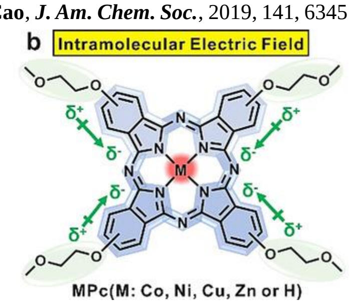
Morphology control and reduction of defects formation





In collaboration with Prof. Jing Cao, ***J. Am. Chem. Soc.***, 2019, 141, 6345





Angew. Chem. Int. Ed., 2021, 60, 6294; ***J. Am. Chem. Soc***., 2021, 143, 18989

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"They created a rechargeable world"
--- nobelprize.org

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Critical Elements Scalability

Cite this: *RSC Advances*, 2012, **2**, 7933–7947

www.rsc.org/advances

REVIEW

Addressing the terawatt challenge: scalability in the supply of chemical elements for renewable energy†

Peter C. K. Vesborg*[a] and Thomas F. Jaramillo[b]

An estimate based on 1 TW x 24 hr :
For Pb-acid batteries, need 100 yrs worth of current lead production;
For Li-ion batteries, need 160 yrs worth of current lithium production;

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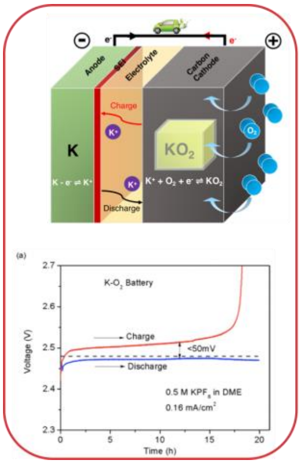
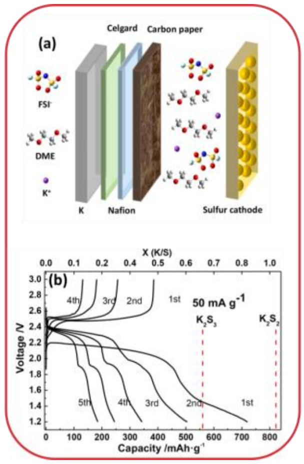
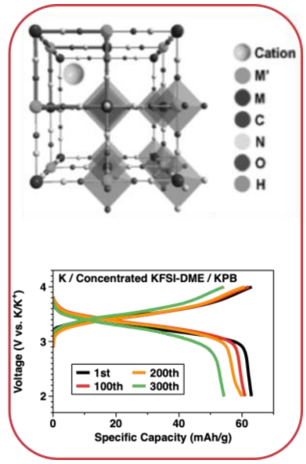
K Battery

K–O_2 K–S K–ion







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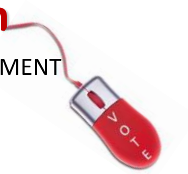
Audience Survey Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT



What % of the world electricity generation comes from renewable energy in the year of 2020?

- 2%
- 10%
- 29%
- 40%

** If your answer differs greatly from the choices above tell us in the chat!*

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Role for hydrogen in future low-carbon energy systems: insights from systems modeling

Dharik S. Mallapragada

ACS-CAS presentation

May 4, 2022

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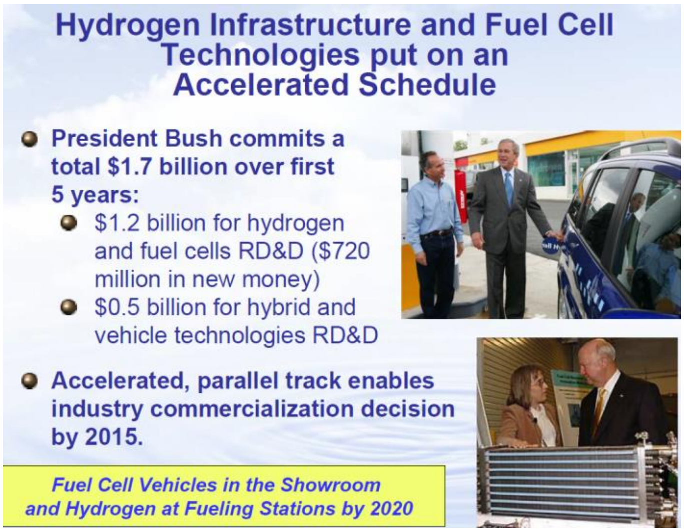
There have been previous waves of interest in the hydrogen economy, so what might be different this time?



Fuel cell cars sold and leased in US as of December 1, 2021: 12,187

1. Sourced from slide 4 of 39 from here: https://www.energy.gov/sites/prod/files/2014/03/f12/hpwgw_doe_paster.pdf

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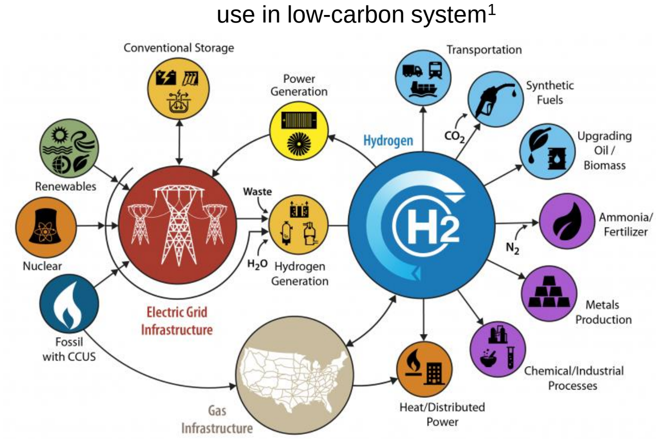
Recent renewed interest in H_2 or H_2-derived carriers appears to focus on enabling decarbonization of across multiple end-uses where direct electricity use may be challenged

Department of Energy vision for H2 use in low-carbon system[1]



Recent U.S. government initiatives:

- Hydrogen Earthshot $1/kg "clean hydrogen" by 2030
- Defining "clean" hydrogen <= 2 kgCO2eq/kg H2
- US DOE hydrogen hubs - $8 Billion
- US Nuclear fleet credit program

Regional initiatives:

- California Low-carbon fuel standard

1. https://www.energy.gov/eere/fuelcells/h2scale

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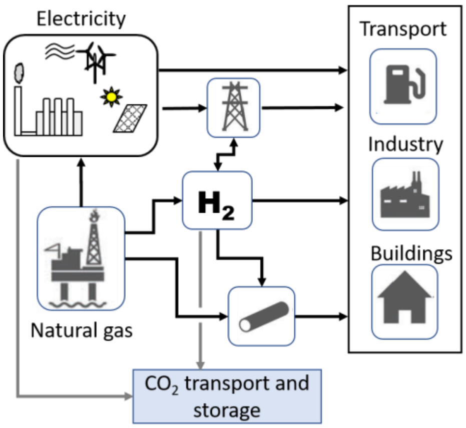
H_2 value proposition influenced by its interactions with other energy related infrastructure (electricity, gas, CO_2) as well as its potential uses across multiple sectors

Sectoral interactions with multiple energy vectors



Questions of interest

- How does sector coupling influence least-cost infrastructure outcomes?
- What are the implications for the design of emerging low-carbon technologies?
- With increased inter-dependency, what are the trade-offs between cost-saving and system resilience and reliability

MITei

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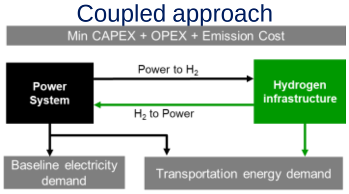
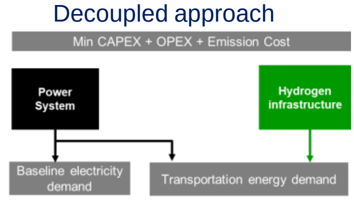
Impact of sector coupling - flexible electrolysis + H2 storage reduces role of dispatchable low-carbon generation (gas) and battery storage in power sector under carbon constraints

Coupled approach

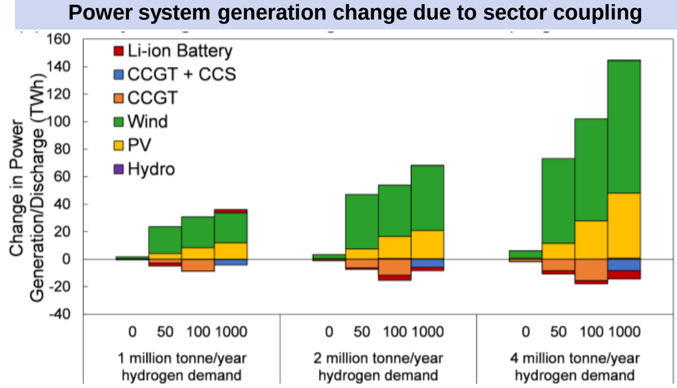


Decoupled approach



Power system generation change due to sector coupling

More generation in coupled approach



Northeast case study, $300/kW electrolyser capital cost

MITei

He, G., Mallapragada, D.S., Bose, A., Heuberger-Austin, C.F. and Gençer, E., 2021. Sector coupling via hydrogen to lower the cost of energy system decarbonization. *Energy & Environmental Science, 2021*.

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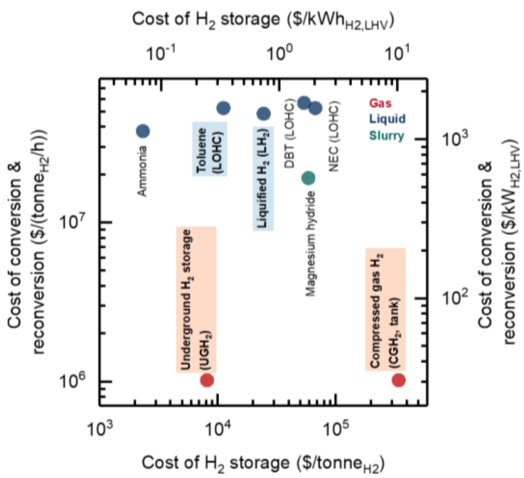
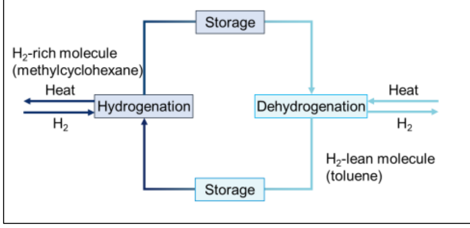
Systems analysis can support innovation in emerging H_2 technologies for production, storage and transport: liquid H2 vs. liquid organic hydrogen carriers

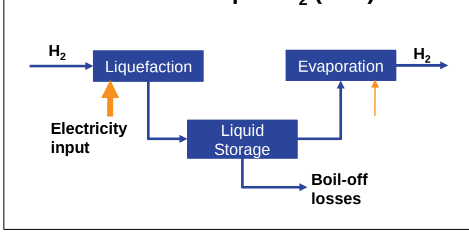


Liquid organic hydrogen carriers (LOHC)



Compatible with existing liquids infrastructure

Liquid H_2 (LH2)

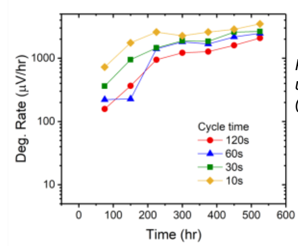


Research in collaboration with Prof. Yang Shao-Horn's group at MIT

Some important areas for hydrogen deployment at scale needing further research

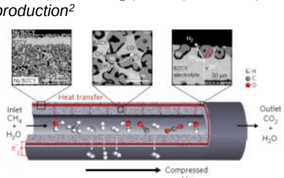
Scalability and durability of electrolysis systems under dynamic operation

- Catalyst loadings for currently PEM electrolyzers: 700 kg Ir/GW [4] → 9 X global production to meet projected electrolyzer deployment in 2030 a net-zero scenario[4]
- Degradation under dynamic operation

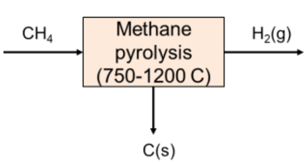


PEM Electrolyzer degradataion under various cycling schemes (Source: ref 1)

Thermo-electrochemical methane reforming for compressed H_2 (and capture ready CO_2) production[2]



Methane pyrolysis[3]

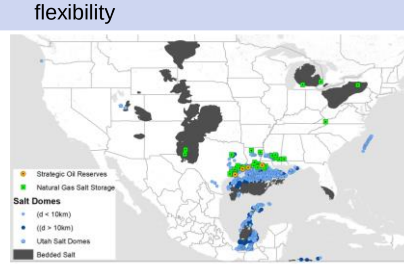


Advances in low-carbon natural gas based H_2 production

- Reducing methane emissions from gas supply chain
- Improving capture rate, co-product generation, process flexibility

Hydrogen storage in geological formations (e.g. salt deposits, depleted oil and gas reservoirs) to provide large-scale energy storage

- 5 facilities existing today use salt deposits



1. Salt deposits and used/unused known salt domes in the US

1. Alia, S.M., et al., *Journal of The Electrochemical Society*, **166**, 2019. 2. Malerod-Field et al., Nature Energy, 2, 923-931, 2017
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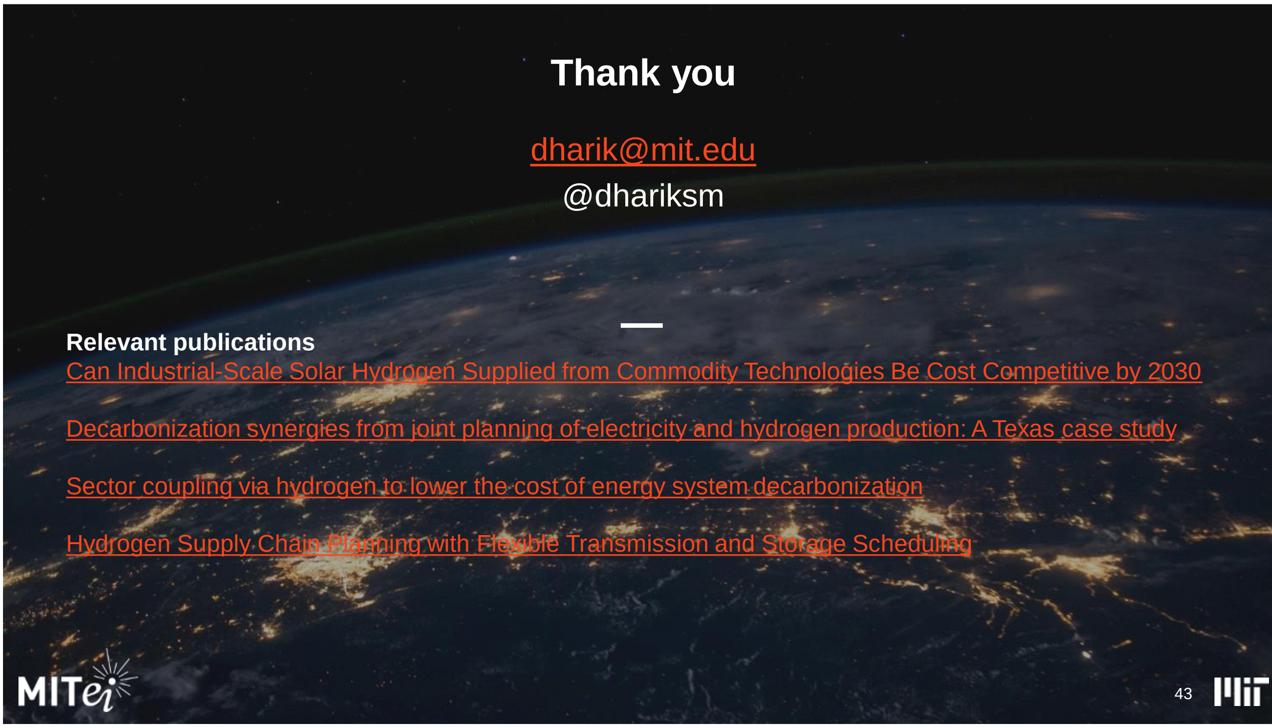
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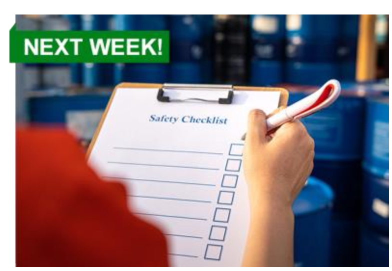

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