SESSION 1

2024 JISEA Annual Meeting

Feb. 26–27, 2024

NREL Transforming ENERGY | Colorado School of Mines | Colorado State University | Howard University Office of Research | Massachusetts Institute of Technology | Stanford University | University of Colorado Boulder

The Scope

- Industry accounts for 40% of all GHG emissions globally and 30% of in the U.S.
- Ag contributes ~10% of total U.S. emissions, not including onsite fossil energy use.
- In 2022, the U.S. produced 15.8 million gallons of SAF; we must scale by 1900% to hit 3 billion gal. by 2030.
- These industries employ 10^{+} million people in the U.S. and contribute trillions of dollars to the GDP.

Challenges and risks for industrial decarbonization include:

High cost and complexity to adopt technologies, few high-TRL solutions, lack of enabling infrastructure and supply chains, capital flow challenges, limited awareness, lacking workforce readiness

SESSION 1

Hard-to-Decarbonize Industries

Day 1: 10:15 a.m.–1:15 p.m.

OVERVIEW

Attendees will delve into the complex **challenges confronting hard-to-decarbonize** sectors in the economy, emphasizing the **need to cultivate extensive collaborations among diverse stakeholders**.

GOALS

Identify **obstacles to decarbonization** in various key industries and **opportunities for strategic coalition-building** to drive action. Attendees will have the opportunity to apply what they learn during the session by **developing the design** parameters for a **national Net-Zero Industry Hubs program**.

SPEAKERS

Chad Reese	Environmental Affairs Manager, San Diego County Regional Airport Authority
Jordan Lambert	Director of Ag Innovation, Colorado State University
Ana Aday	Materials Science Researcher, Building Technologies and Science Center, NREL
Rolf Weberg	Director, Natural Resource Research Institute

SESSION 1

Hard-to-Decarbonize Industries

Day 1: 10:15 a.m.–1:15 p.m.

Chad Reese

Environmental Affairs Manager
San Diego County Regional Airport Authority

SAN DIEGO INTERNATIONAL AIRPORT
LET'S GO.

Sustainability at SAN

Chad Reese

Environmental Affairs Manager

February 26, 2024

"It's too busy."
storms
rain
lightning
Air plane
polar bears losing homes
gas
plants doing well.
gas
ice melting
gas
plants dying
charlotte

fluffy clouds
Happy sun
birds singing
Happy snow monster (yeti)
tweet
Happy Flowers
Snowy mountain
Trees growing
Magic is working
charlatte
Reed

San Diego International Airport

51-Gate
Large Hub Airport

Over 22 Million
Passengers

Busiest Single Runway
in the US

Confined to 661 Acres

Grow to 37 Million
Passengers by 2035

SAN's Definition of Sustainability

"Plan and build an enduring and resilient customer-focused enterprise by effectively managing our financial, social, and environmental risks, obligations and opportunities."

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Sustainability Timeline

Sustainability Policy **Attorney General MOU**	2008	Resource conservation and social responsibility Emissions reduction and fleet electrification
Sustainability Reporting	2011	Data tracking, transparency and reporting using the Global Reporting Initiative (GRI) framework
Airport Carbon Accreditation	2016	Annual GHG emissions inventory and minimization of Authority's impact on climate change
Airport Sustainability Declaration	2017	Continued commitment to initiatives that improve airport sustainability and resilience
Sustainability Management Plans	2019	7 separate plans that serve as a framework for environmental sustainability initiatives

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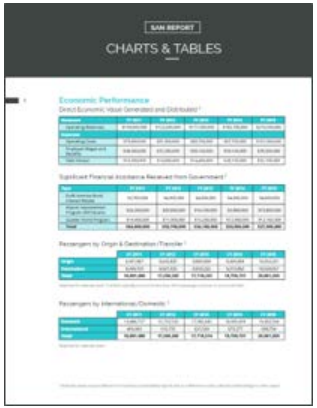
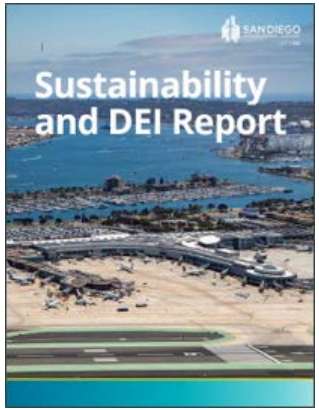
SAN Sustainability Reporting History





2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023

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Sustainability vs. ESG

Sustainability

- Balanced approach to operational excellence (3BL)
- Existing Authority Framework
  - Environmental
  - Social
  - Economic
- Impact reporting
- Audience = community

ESG

- Emphasis on managing key risks & opportunities facing the organization
- New Authority Framework
  - Environmental
  - Social
  - **Governance**
- Financial reporting
- Audience = investors, ratings agencies

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“Double Materiality”

Financial Materiality

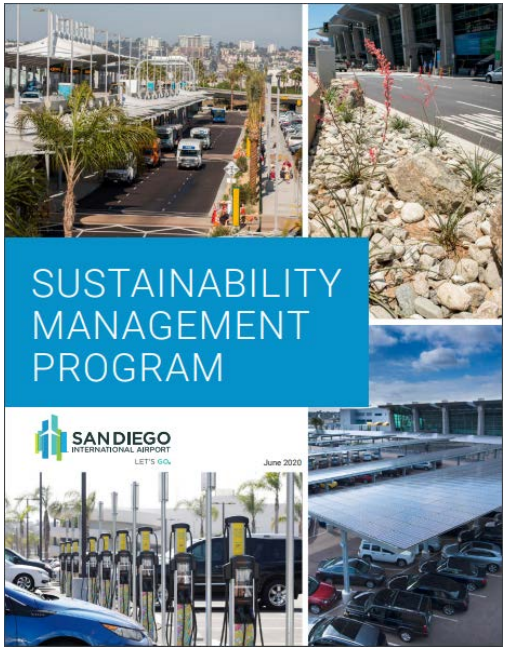
- Issues that affect the organization (+/-)
- e.g., climate risk, governance structure, announced sustainability goals

Impact Materiality

- External influences of the organization and its operations (+/-)
- e.g., noise, air quality, volunteerism

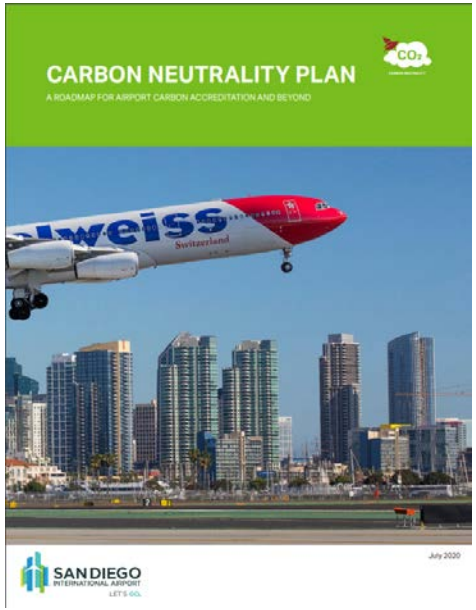
Partnerships

Sustainability Management



san.org/green

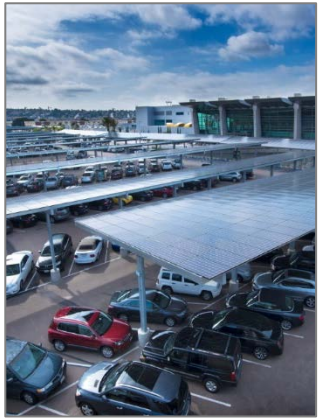
Carbon Neutrality



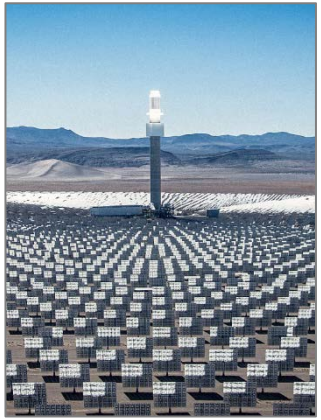
The CNP establishes the Authority's strategy for managing **air quality and greenhouse gas** (GHG) emissions.

Carbon Neutrality

Authority-Controlled Emissions



Onsite Renewable Electricity and Batteries



Grid-Delivered Renewable Electricity

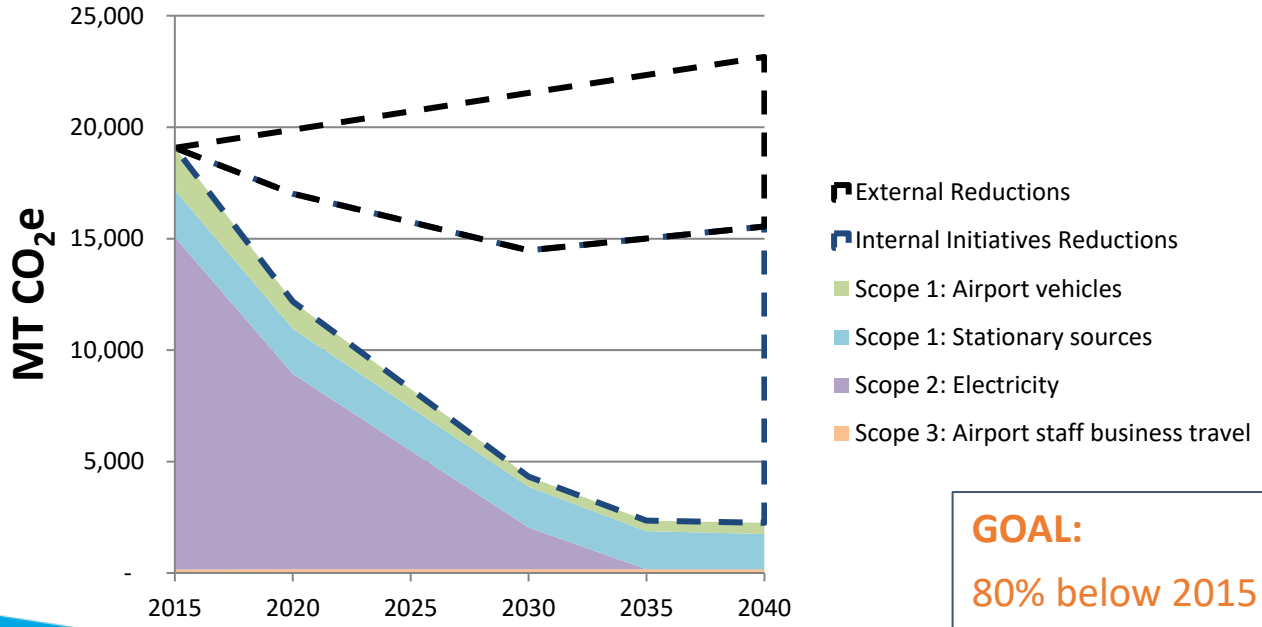
High-Performance Facilities

Alternative Fuel Equipment

Electric Fleet Vehicles

Carbon Neutrality

Authority-Controlled Emissions with Reductions



GOAL:

80% below 2015 by 2035

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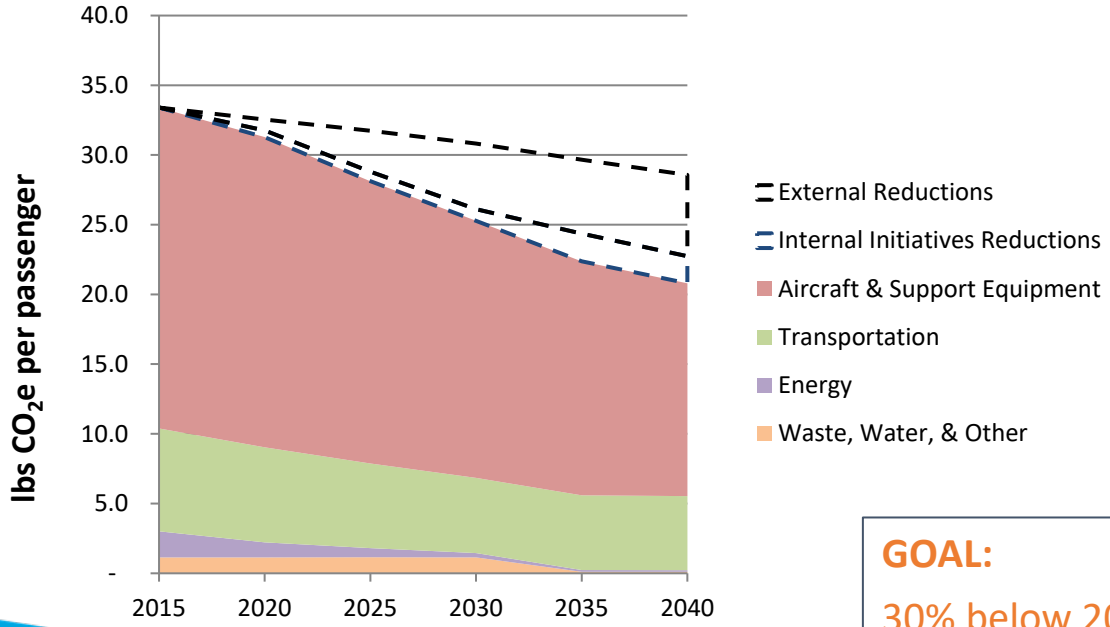
Carbon Neutrality

Airport-Wide Emissions with Reductions



GOAL:

30% below 2015 by 2035

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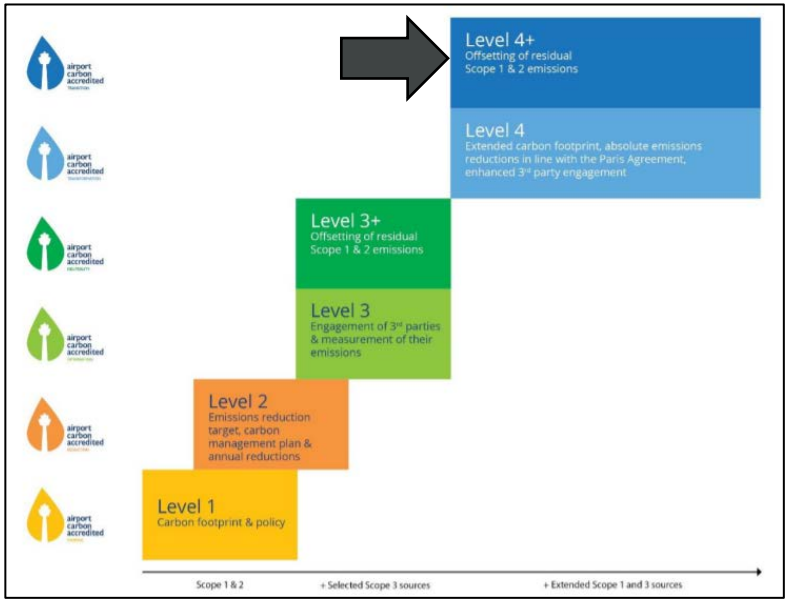
Annual Greenhouse Gas Reporting

Goals

- Minimize the Authority's direct operational impact on climate change and local air quality
- Help airport partners minimize their impact on climate change

Initiatives

- Currently certified at Level 4+ in Airport Carbon Accreditation program
  - 'Carbon Neutral' Airport (2nd in N.A.)
- Reduce Scope 1 and 2 emissions
- Stakeholder Engagement Plan to reduce Scope 3 emissions



airport carbon accreditation

The Good Traveler

- 25 partner airports
- 700 million miles of travel offset
- San Diego regional partners
- Purchase a certified carbon offset
- Donate to an environmental nonprofit organization

THE GOOD TRAVELER
LEAVES NO TRACE

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New Terminal 1

Sustainability

Sustainability is at the heart of everything we do at SAN. The New T1 construction and design will reflect our industry-leading commitment to sustainability through energy and water conservation, as well as clean-air and zero-waste initiatives. Our goal is to achieve LEED Gold certification for the New T1.

Sustainable features will include:

- Expanded electric vehicle charging
- Solar power
- Hydrant fueling system, eliminating the need for tanker trucks
- Electric shuttle service
- Expanded stormwater system

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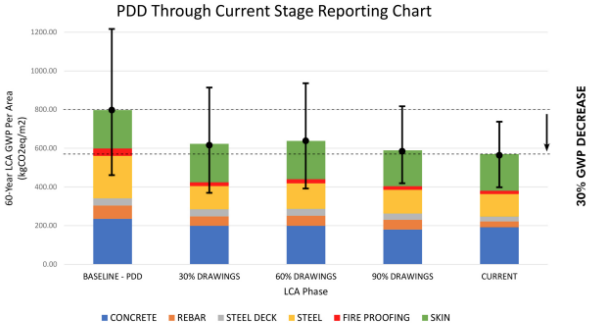
NT1 Embodied Carbon

Embodied Energy: Carbon Reduction Strategies

LCA Overview



Building Life Cycle Impact Reduction 3 Points

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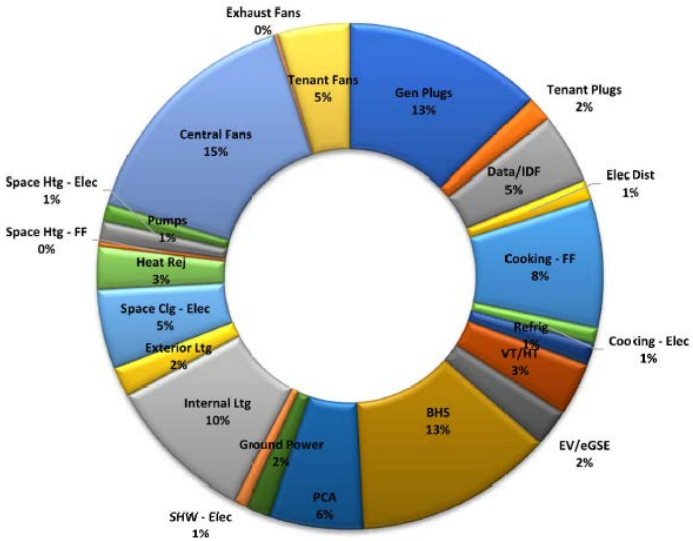
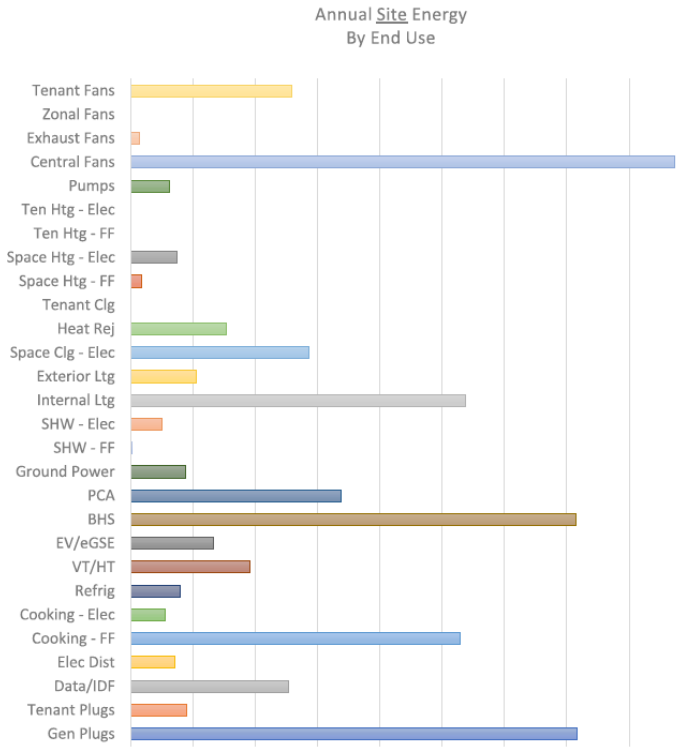
NT1 Operational Carbon & Site Energy



Annual Operational Carbon



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NT1 Operational Carbon & Site Energy

i. Project Goals
The project shall be designed to meet LEED Silver requirements of the USGBC and the California Title 24 Building Energy Efficiency Standards as described in Section E.3.5. In addition to these requirements the Authority has established a minimum Energy Use Intensity (EUI) goal for the project at 45 EUI (excluding process loads) and 90 EUI (including process loads). Further credit will be given for designs that exceed the minimum requirements and meet the targets described in Table E.1.

Table E.1 Energy Performance Goals

Minimum Requirements	Desirable	Stretch Goal
< 45 kBtu/SF (non-process) < 90 kBtu/SF (total)	< 40 kBtu/SF (non-process) < 80 kBtu/SF (total)	< 35 kBtu/SF (non-process) < 70 kBtu/SF (total)

The EUI shall be expressed as energy per square foot per year, and shall be calculated by dividing the total energy consumed by the building in one year (measured in kBtu) by the total gross floor area of the building (measured in SF). These goals may be subject to refinement as the design evolves.

ii. Building Energy Modeling
A building energy model shall be developed at each project phase in order show achievement of project goals and to inform the design. The modeled energy usage shall be used to refine and establish design energy consumption targets (representing no more energy consumption than allowed by the requirements in Table E.1), assess and optimize passive design and the application energy efficiency measures, and provide the inputs required for life cycle cost analysis. A list of potential opportunities to support attainment of the goals is provided in Section E.3.5.iii. The Contractor shall coordinate with the Airport to establish a consistent set of assumptions for process energy use.

Strategic Energy

The STEP addresses key issues of energy efficiency and conservation **including on-site energy generation and storage**, and enhanced monitoring of key energy metrics.

Table 22: Phase 2 Energy Projects

Phase 2 Energy Project	New Capacity	Year	Funding Mechanism	Goal Alignment: Energy Efficiency	Carbon Neutrality	Interdependance a. Resilience	Cost Containment	Energy Leadership
Existing Central Plant Upgrade	+ 900 tons	2022	T1RP Funding	•		•	•	
Photovoltaic Solar	2 MW	2023	PPA / CIP		•	•	•	•
Battery Storage	4 MWh	2023	PPA / Other		•	•	•	•
Photovoltaic Solar	2 MW	2025	PPA / CIP		•	•	•	•
Re-Evaluate Potential for Additional Photovoltaic Solar	2 MW	2025	PPA / CIP		•	•	•	•
Energy Efficiency projects identifies through auditing process		Every 5 years	On-bill financing / CIP	•	•	•	•	•

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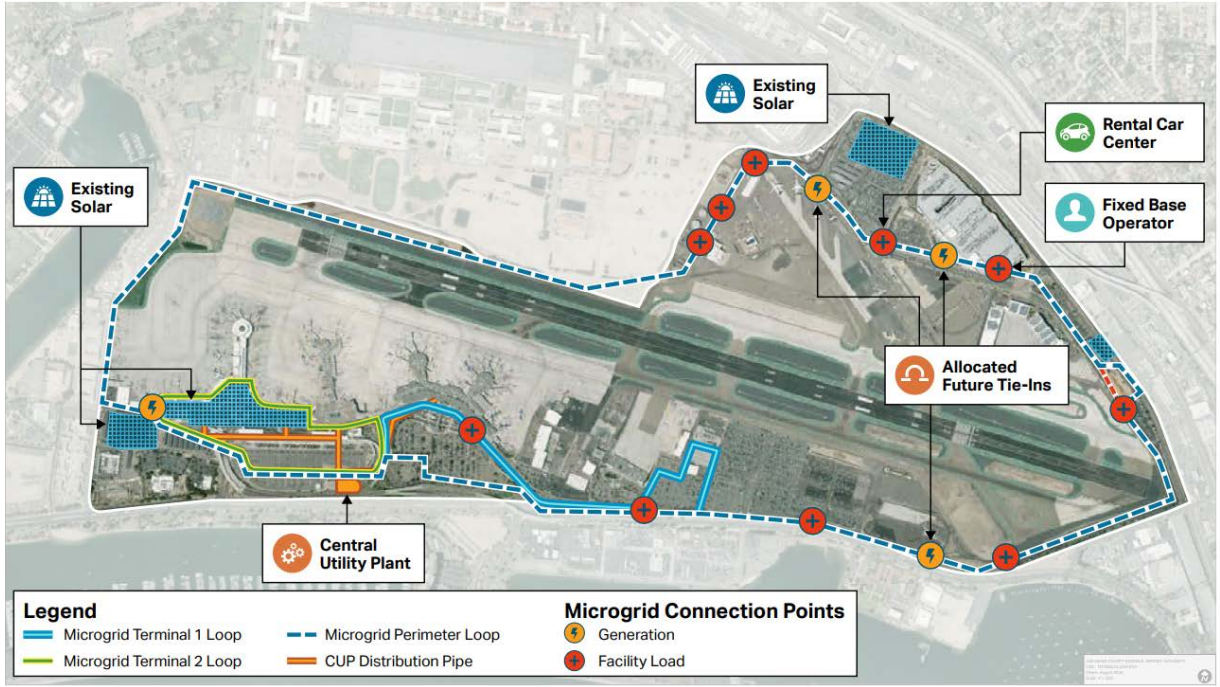
Energy Resilience Opportunities



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PV Solar + Battery Storage

5.5 MW On-Site PV Solar

2 MW/4 MWh Battery Storage

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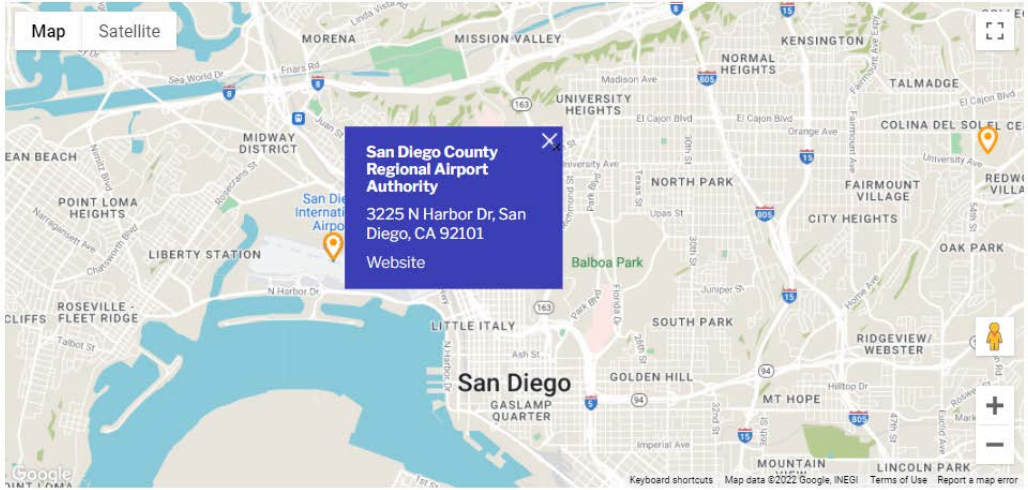
100% Grid-Delivered Renewable Energy

Membership Business Directory Power100 Champions Member Resources



SAN DIEGO COMMUNITY POWER

SAN DIEGO INTERNATIONAL AIRPORT
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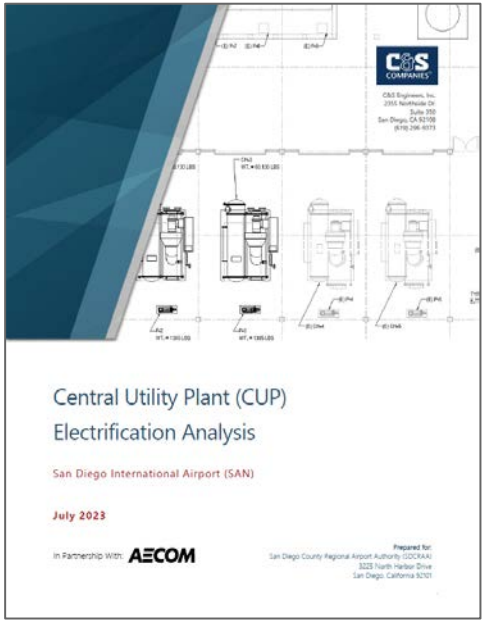
Central Plant Electrification



The **CUP Electrification Analysis** demonstrates how to transition most airport operations from natural gas.

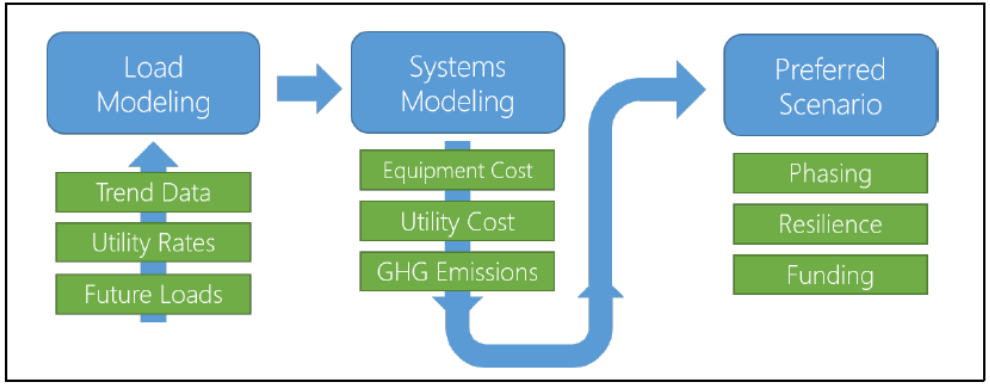
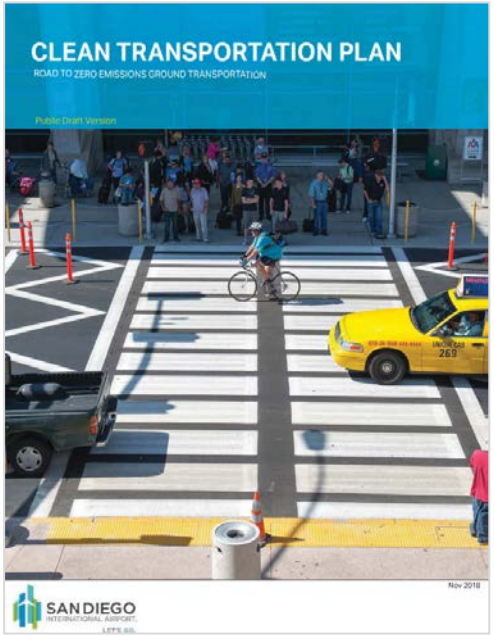
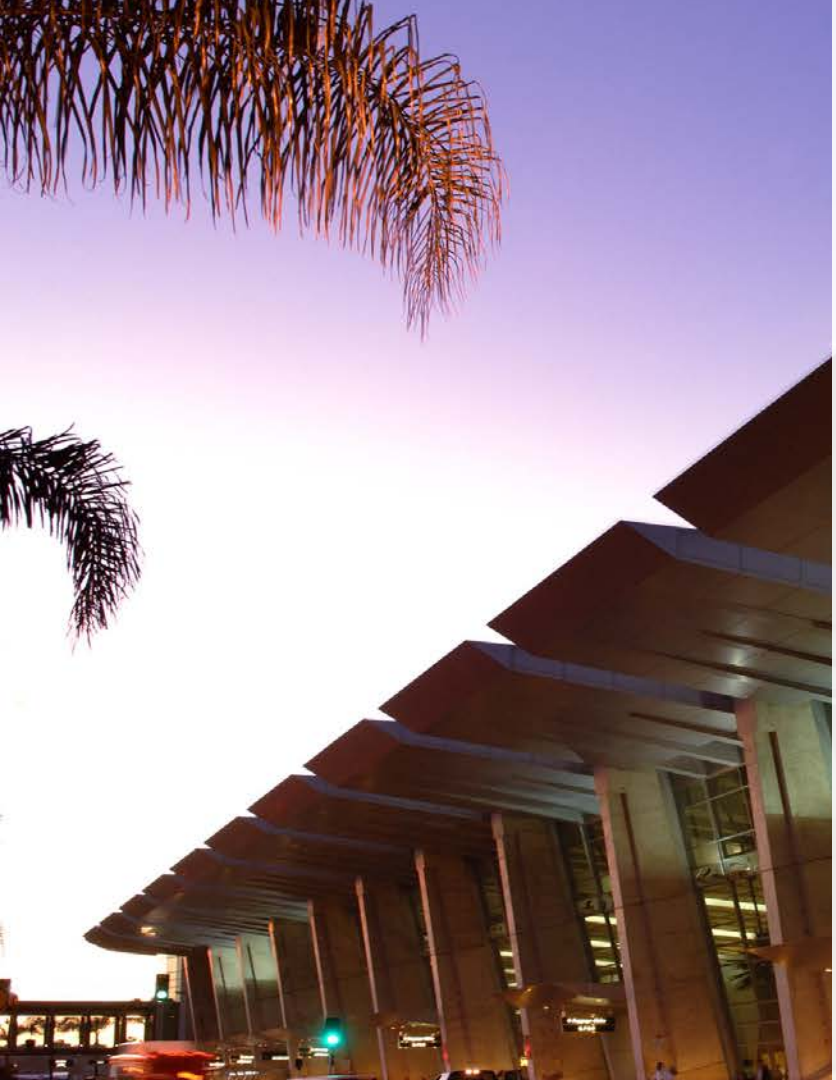


Figure 1. Scenario Analysis Process

Clean Transportation



The CTP is a framework for managing all **ground transportation emission sources**, including all vehicles and equipment accessing and operating at the Airport.



ENVISION™

Parksmart℠

Clean Vehicles

Electric Airside Vehicles and Equipment

Airside GSE Charging

Renewable Diesel at SAN

March 16, 2023: Received first shipment

- Used in all diesel-powered airside (non-road) vehicles and equipment, such as baggage tugs, belt loaders, and firefighting vehicles.
- 34 percent of all airside diesel vehicles and equipment at SAN are now "alternative fuel" because of the switch from petroleum diesel to renewable diesel.
- With the addition of renewable diesel, the total percentage of alternative fuel vehicles and equipment at SAN (including electric, propane, and renewable diesel) is now 74%.

SAN DIEGO INTERNATIONAL AIRPORT LET'S GO. NEWS

Contact: Larisa Casillas | O: 619.400.2578 | C: 619.984.0531 | E: lcasilla@san.org

San Diego International Airport Begins Using Renewable Diesel for Airside Equipment

SAN DIEGO – April 11, 2023 – The first shipment of renewable diesel has arrived at San Diego International Airport (SAN).

Renewable diesel can reduce emissions by up to 75 percent or more compared to petroleum diesel. The sustainable fuel is now being used in all diesel-powered airside (non-road) vehicles and equipment, such as baggage tugs, belt loaders, and firefighting vehicles. Approximately 30 percent of all airside diesel vehicles and equipment at SAN are now "alternative fuel" because of the switch from petroleum diesel to renewable diesel. With the addition of renewable diesel, the total percentage of alternative fuel vehicles and equipment at SAN (including electric, propane, and renewable diesel) is now 64%.

"San Diego International Airport is thrilled to begin using renewable diesel to reduce the airport's carbon footprint, improve local air quality, and help meet our sustainability goals. We thank our airlines for their cooperation and partnership during this process," said Kimberly Becker, President and CEO of the San Diego County Regional Airport Authority.

"SAN Fuel Company is proud to partner with San Diego County Regional Airport Authority to bring renewable diesel to SAN," said Scott Carrington, Fuel Category Manager at Southwest Airlines and Chair of the SAN Fuel Company. "This partnership is a great example of collaboration between the airport and its airline business partners and it provides a model for others to replicate."

What's in renewable diesel?

Renewable diesel is a sustainable fuel made from vegetable oil, animal fats, and agricultural waste that would otherwise end up in a landfill. It is chemically identical to fossil fuel-derived diesel, and considered a "drop-in" fuel, meaning no modifications are needed for its storage or to use it in diesel engines.

Renewable diesel fuel is delivered to the airport in a renewable diesel-powered truck and is an initiative within the Airport Authority's Clean Transportation Plan.

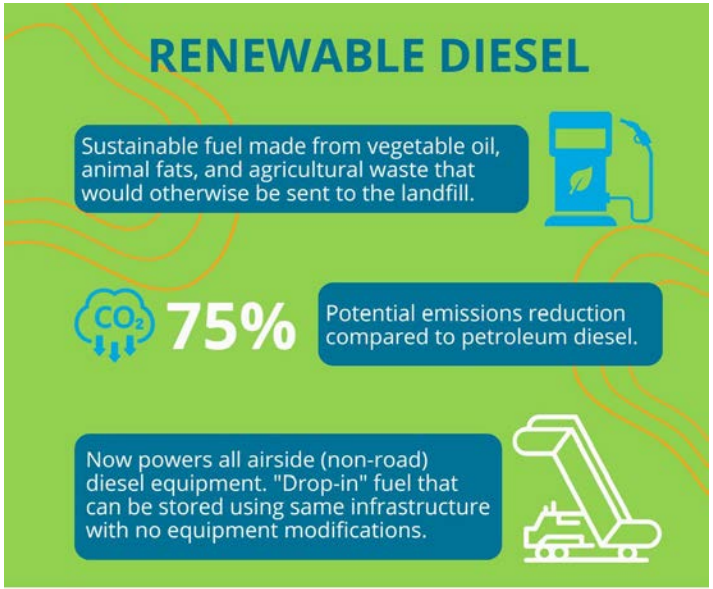
ABOUT SAN DIEGO INTERNATIONAL AIRPORT (SAN)
Owned and operated by San Diego County Regional Airport Authority (Airport Authority), San Diego International Airport (SAN) is one of the busiest single-runway commercial service airports in the world and the third-busiest airport in California. SAN contributes nearly $12 billion in economic activity for the region by connecting the world to San Diego and San Diego to the world. In November 2021, the Airport

(More)

Renewable Diesel is…

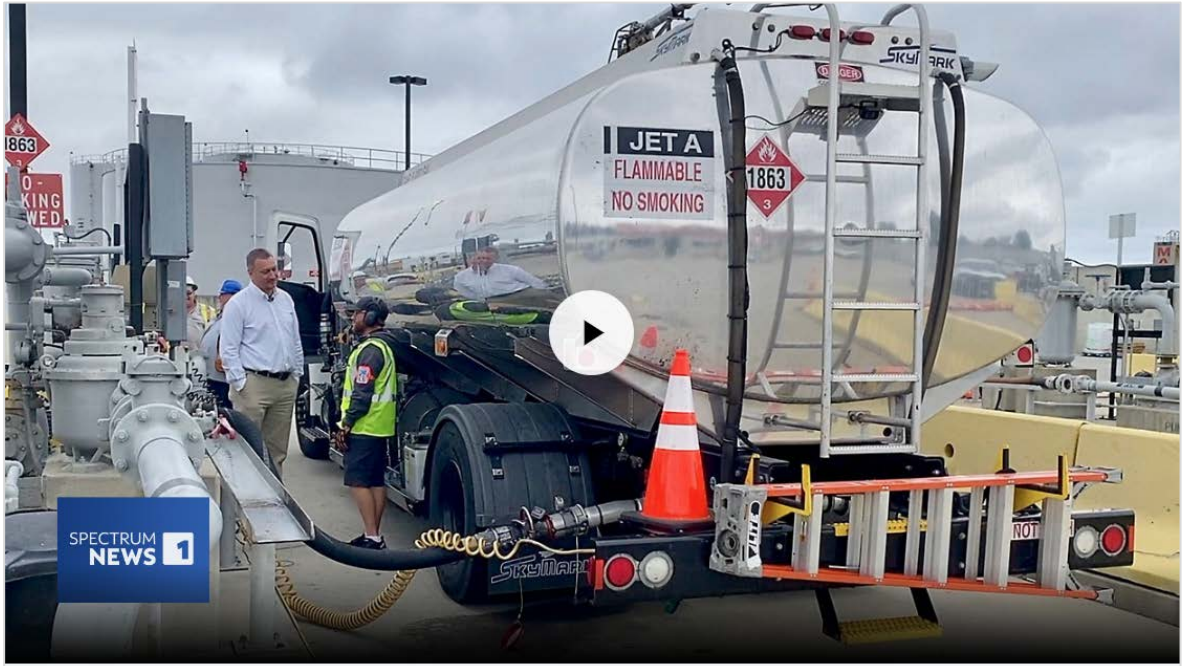
…not biodiesel

- Sustainable (made from vegetable oil, animal fats, agricultural waste)
- Refined to the same standard (ASTM-D975) as petroleum-based diesel
- Chemically identical to fossil fuel-derived diesel
- A “drop-in” fuel that can be transported and stored using the same infrastructure with no equipment modifications necessary
- Similar in shelf life to Ultra-Low Sulfur Diesel (ULSD)
- Emits about 10 pounds of carbon dioxide (CO_2) per gallon of fuel (in contrast to roughly 22.4 pounds of CO_2 per gallon of fuel from burning petroleum diesel)*



U.S. Energy Information Administration
https://www.eia.gov/tools/faqs/faq.php?id=307&t=9

A Collaborative Process



(Spectrum News/Bree Steffen)

https://spectrumnews1.com/ca/la-west/news/2023/08/01/san-diego-international-airport-begins-using-renewable-diesel?cid=id-app15_m-share_s-web_cmp-app_launch_august2020_c-producer_posts_po-organic

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Beyond Compliance

One step ahead of the Zamboni

- Beginning January 1, 2024, all California fleets subject to this regulation are required to procure and only use R99 or R100 renewable diesel fuel in all vehicles subject to the Off-Road Regulation, with some limited exceptions.
- 60-day advanced notice provided.
- All fleet teams at SAN already in compliance.

CALIFORNIA AIR RESOURCES BOARD

CARB approves amendments to Off-Road Regulation to further reduce emissions

Program is expected to yield more than $5 billion in health benefits from 2024 to 2038

DATE November 17, 2022
RELEASE NUMBER 22-45

CONTACTS
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Office of Communications
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CATEGORIES
Topics Construction & Earthmoving Equipment, Agriculture
Programs In-Use Off-Road Diesel-Fueled Fleets Regulation, In-Use Off-Road Mobile Agricultural Equipment

Sacramento —The California Air Resources Board (CARB) today approved amendments to the In-Use Off-Road Diesel-Fueled Fleets Regulation (Off-Road Regulation) aimed at further reducing emissions from the off-road sector. The amendments will require fleets to phase-out use of the oldest and highest polluting off-road diesel vehicles in California; prohibit the addition of high-emitting vehicles to a fleet; and require the use of R99 or R100 renewable diesel in off-road diesel vehicles.

Off-road vehicles subject to the amendments are used in construction, mining, industrial operations, and other industries. The amendments phase-in starting in 2024 through the end of 2036 and include changes to enhance enforceability and encourage the adoption of zero-emission technologies.

Innovative Solutions (with Diesel)

DHL Express to Cut Ground Emissions with Mobile Charging Carts

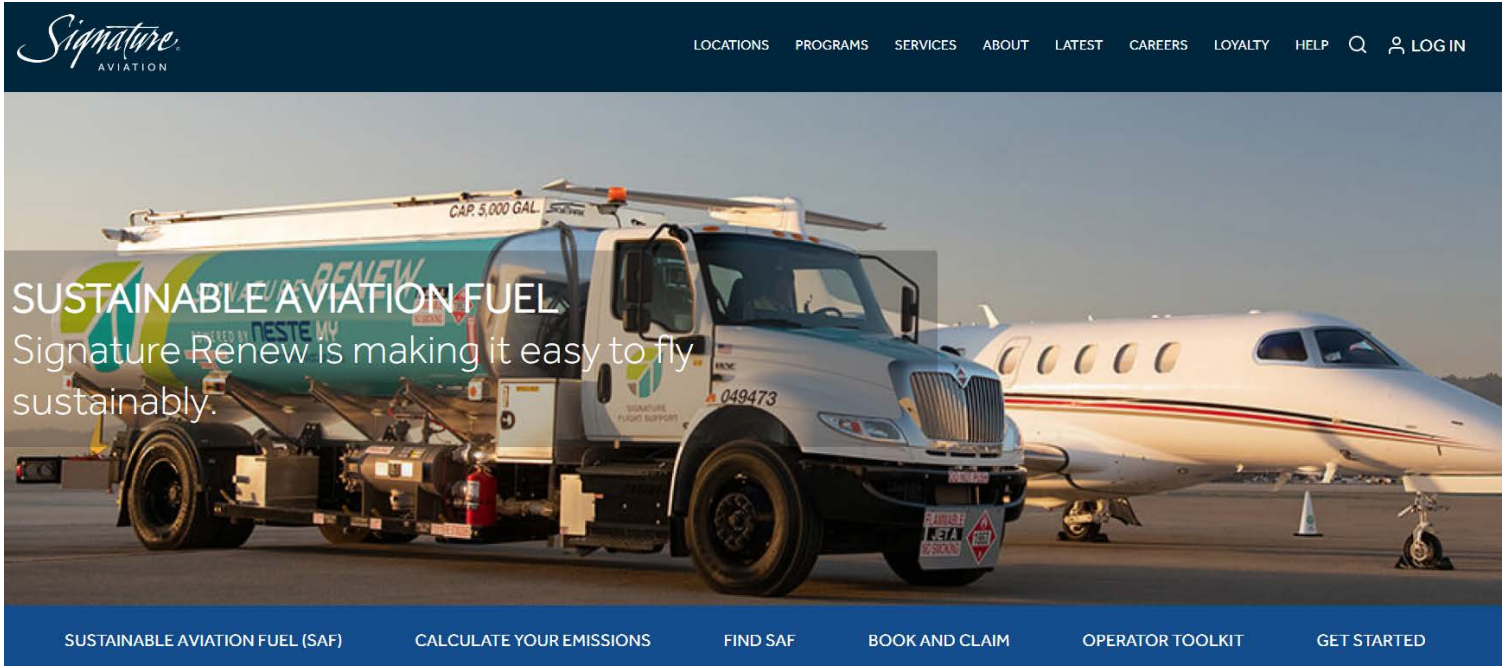
https://www.groundhandlinginternational.com/content/news/dhl-express-to-cut-ground-emissions-with-mobile-charging-carts/

Innovative Solutions (with Hydrogen)

Universal Hydrogen Completes First Full Demonstration of AmpCart H2

https://www.businesswire.com/news/home/20240220463846/en/Universal-Hydrogen-Completes-First-Full-Demonstration-of-AmpCart-H2

Sustainable Aviation Fuels



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Thank You!

Email: creese@san.org | Phone: 619.400.2780

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SESSION 1

Hard-to-Decarbonize Industries

Day 1: 10:15 a.m.–1:15 p.m.

Jordan Lambert

Director of Ag Innovation
College of Ag Sciences, CSU Spur

Why Is Decarbonizing Agriculture Hard?

Jordan Kraft Lambert
Director of Ag Innovation,
College of Ag Sciences, CSU Spur

February 2024

Why Is Decarbonizing ~~Agriculture~~ Food Hard?

Jordan Kraft Lambert
Director of Ag Innovation,
College of Ag Sciences, CSU Spur
February 2024

Why Is Decarbonizing Food Hard?

Agenda

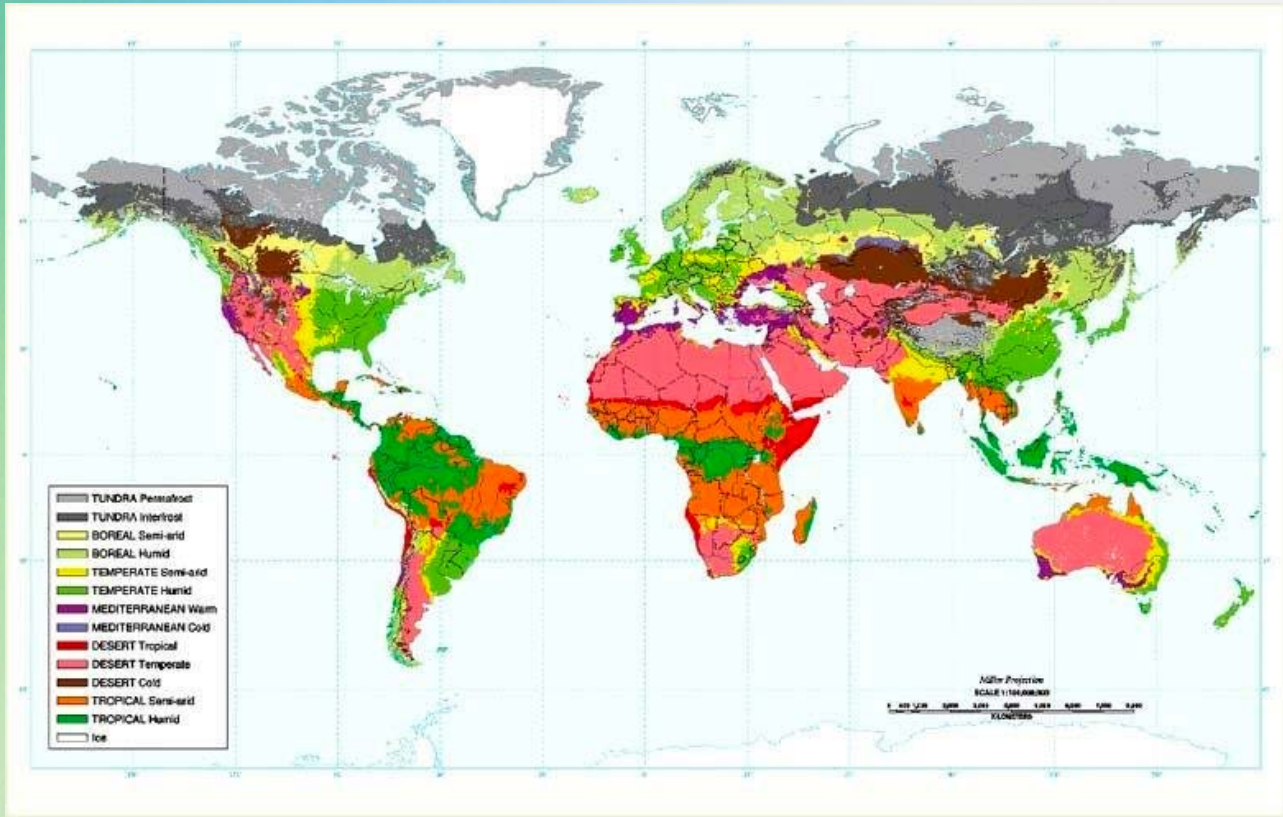
- Why it’s hard
- What’s been done
- What must be done
- Help!

Food Production Systems Are Diverse

One solution doesn’t fit all

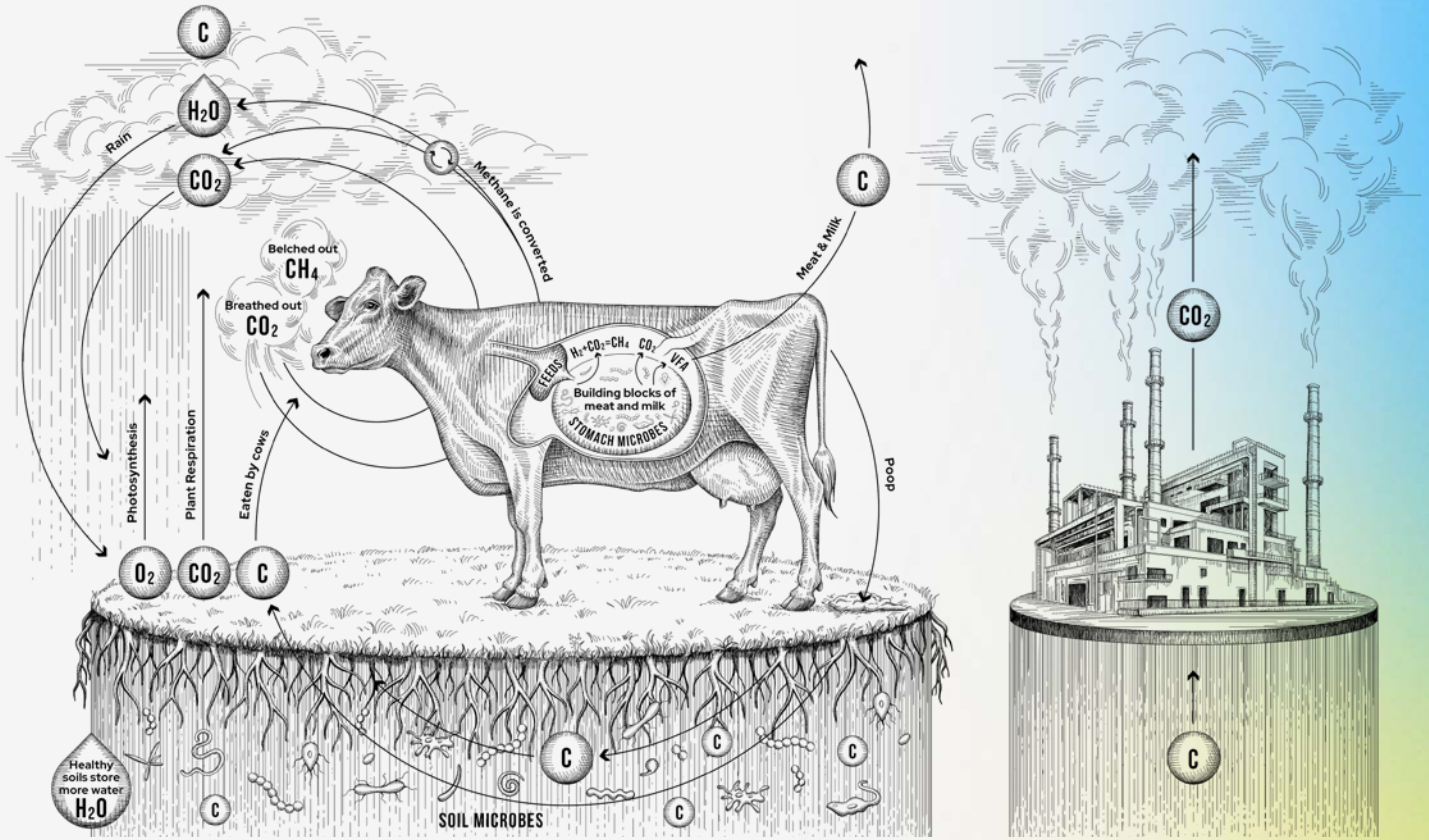
Food Production Geographies Are Diverse

Even within a system, what works in one biome may not in another



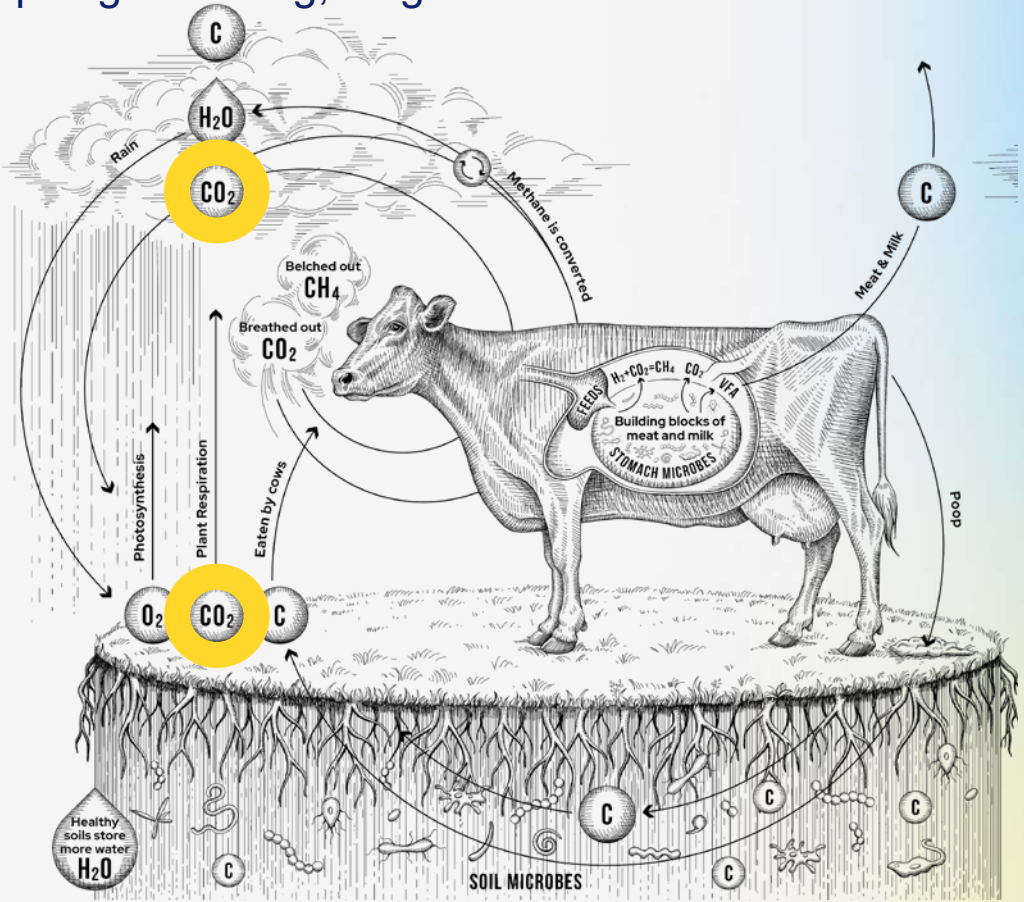
Carbon Release Is A Feature, Not A Bug

Cow Carbon Cycle —————— *vs* —— *Fossil Fuels*



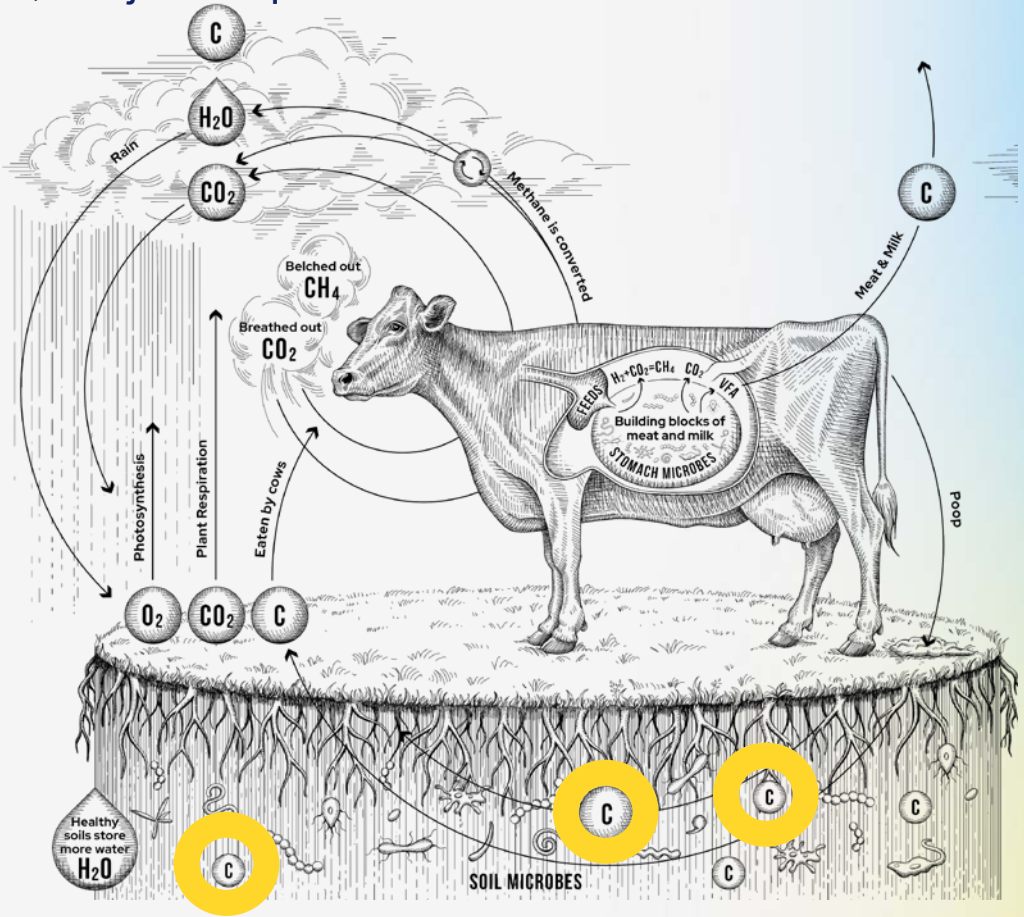
Carbon Release Is A Feature, Not A Bug

Plants done been respiring for a long, long time



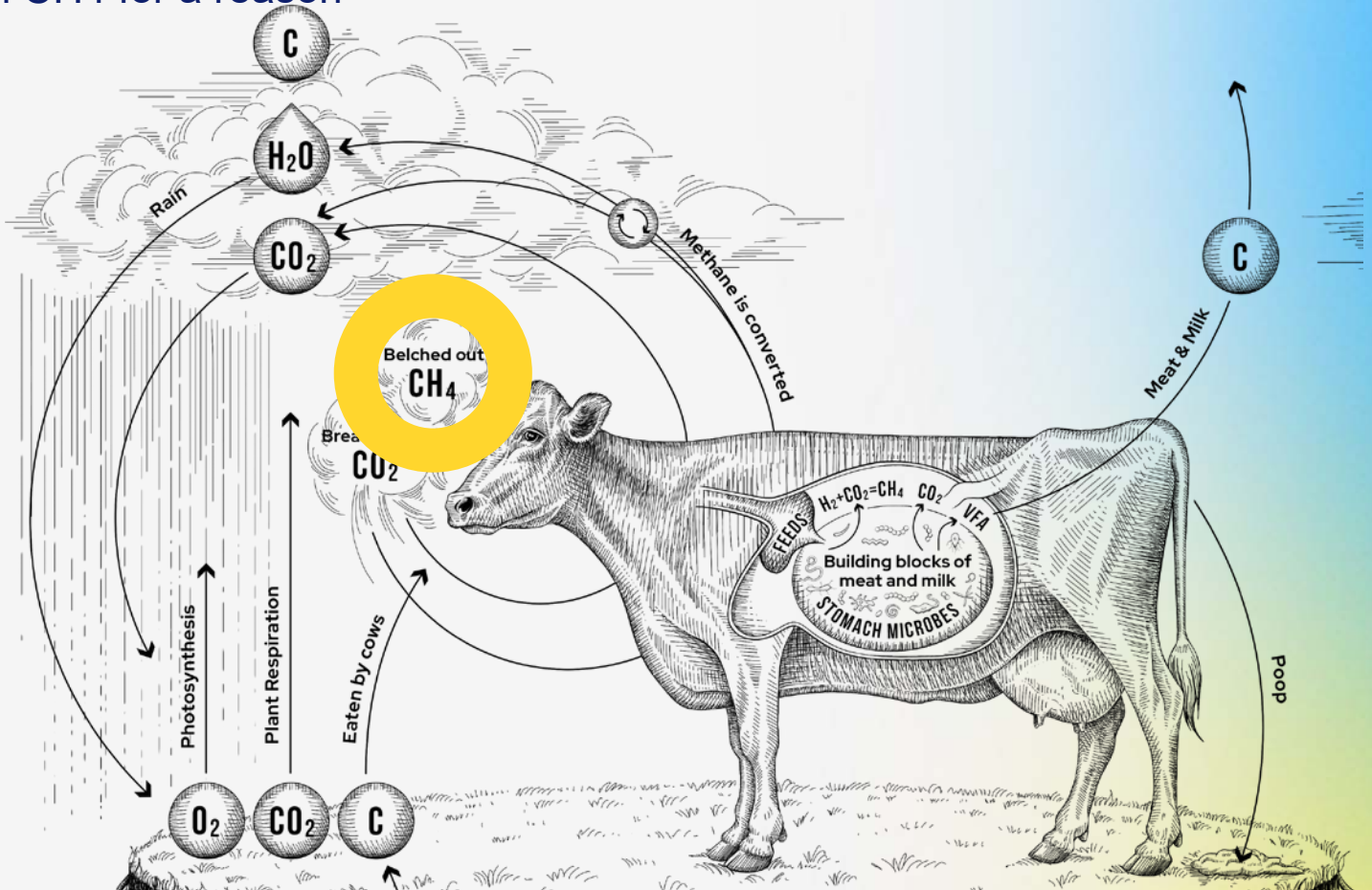
Carbon Release Is A Feature, Not A Bug

Productive soil cycles, not just sequesters



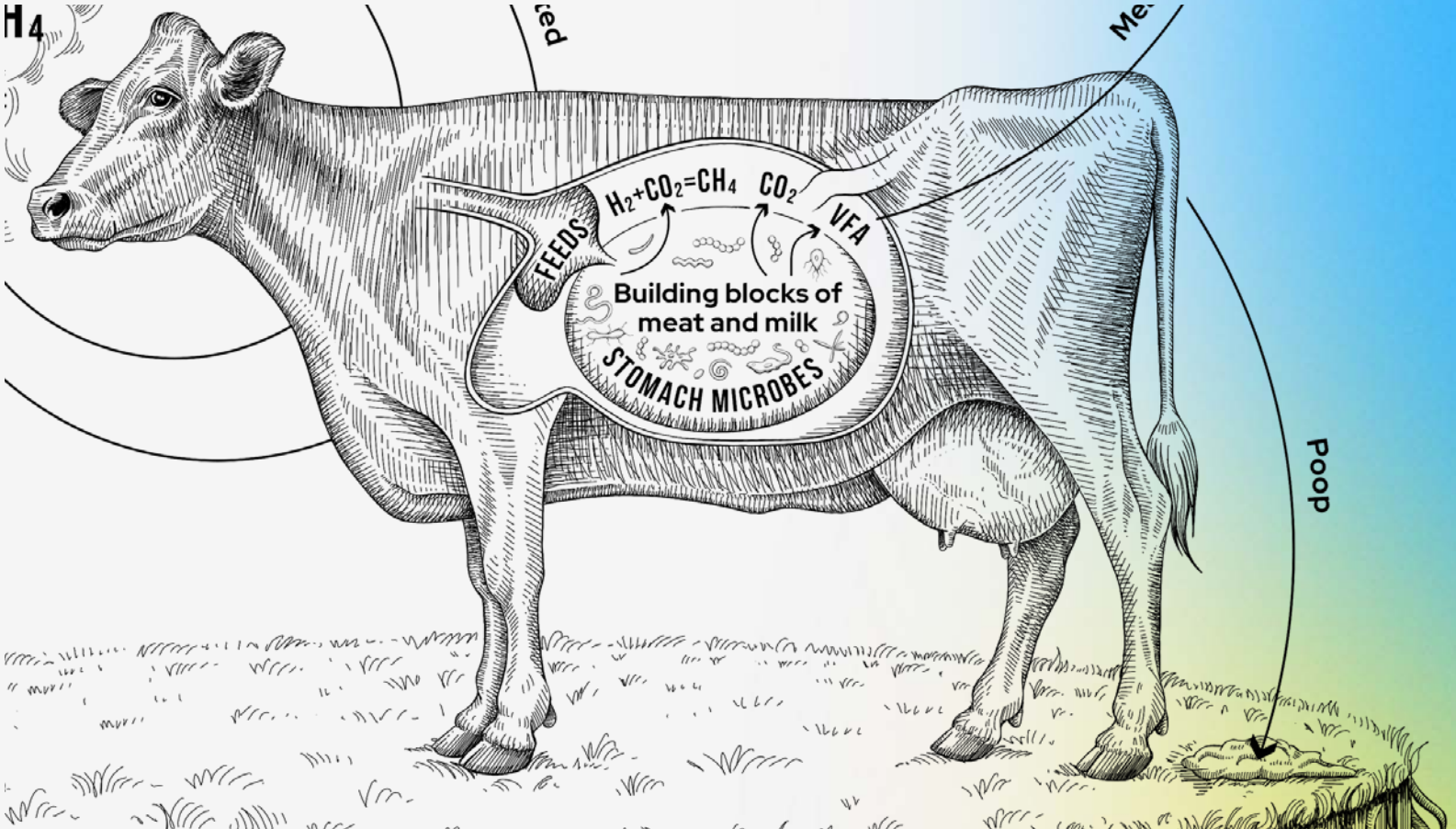
Carbon Release Is A Feature, Not A Bug

Cows belch CH4 for a reason



Carbon Release Is A Feature, Not A Bug

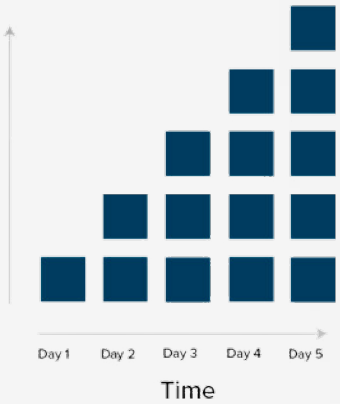
Cows belch CH4 for a reason



Our Understanding Of Relevant Gases Is Evolving

= Pulse of CO_2

Stock Gas
Carbon dioxide (CO_2)



Stock gases will accumulate over time, because they stay in the environment.

= Pulse of CH_4

Flow Gas
Methane (CH_4)

Flow gases will stay stagnent, as they are destroyed at the same rate of emission.

UC DAVIS CLEAR Center

Based on research by Myles R. Allen, Keith P. Shine, Jan S. Fuglestvedt, Richard J. Millar, Michelle Cain, David J. Frame & Adrian H. Macey.
Read more here: https://rdcu.be/b1t7S

US Dairy Is A Food Production System Worth Improving

In 2020, American Dairy Cows Supplied Enough Nutrition To Meet:

169 million people's Protein requirements

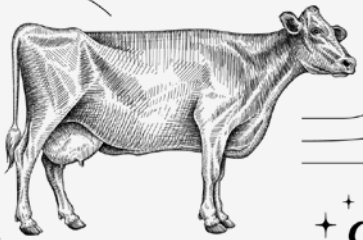
Protein from dairy products is complete - meaning it contains all 9 essential amino acids that keep your body strong.

29% of American Choline requirements

Cholines supports your memory, mood, and muscle control, as well as forms the membranes that surround your body's cells.

57% of American vitamin B12 requirements

Vitamin B12 is essential for making the neurotransmitters that help you feel happy and sleep well - serotonin and dopamine.



54% of American vitamin D requirements

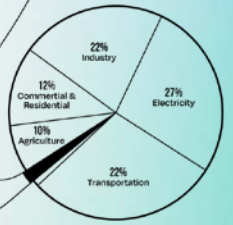
Vitamin D makes your muscles move, makes your nerves carry messages between your brain and body, and builds strong bones.

71 million people's Energy requirements

Your brain uses energy to think and your body uses energy to move.

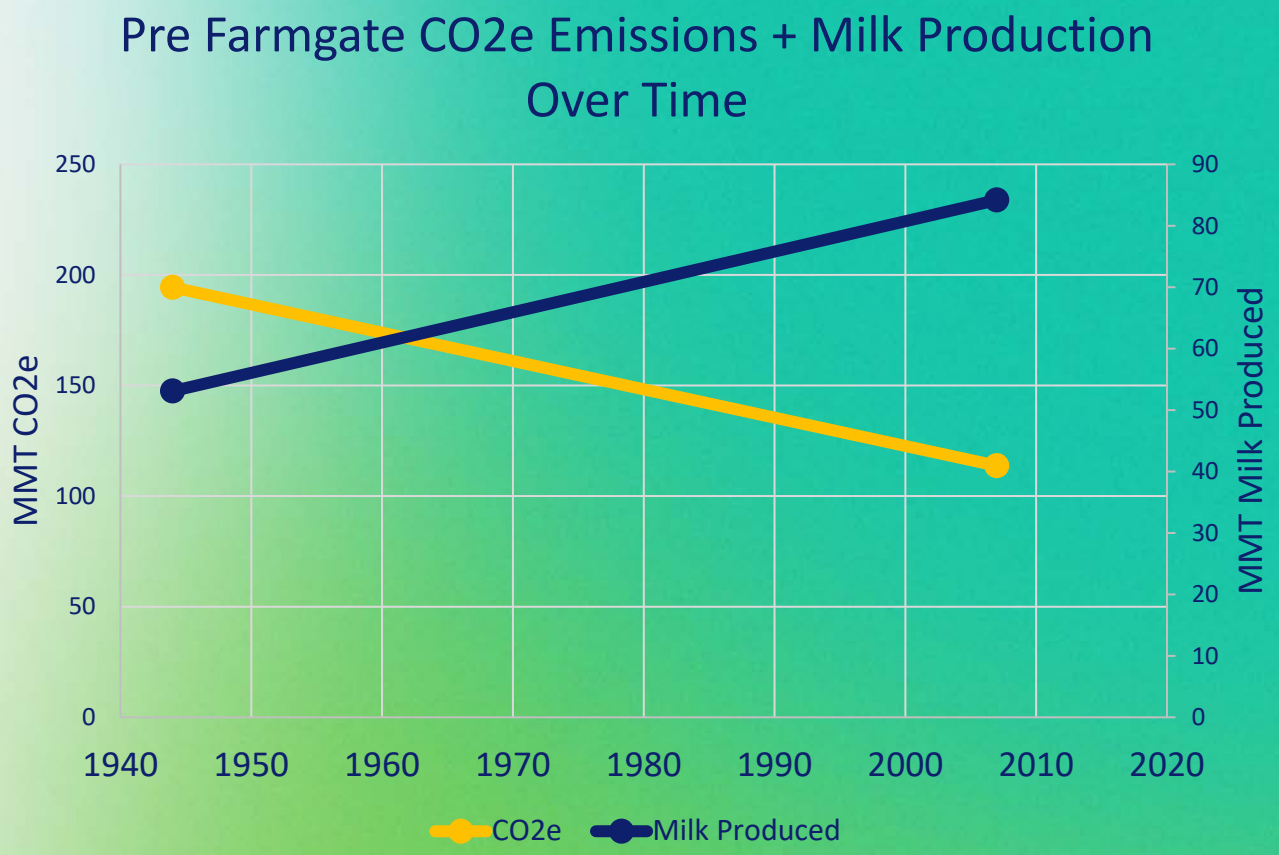
39% of American vitamin A requirements

Vitamin A helps you defend against infection and keeps your eyes, heart, lungs, and reproductive organs healthy.



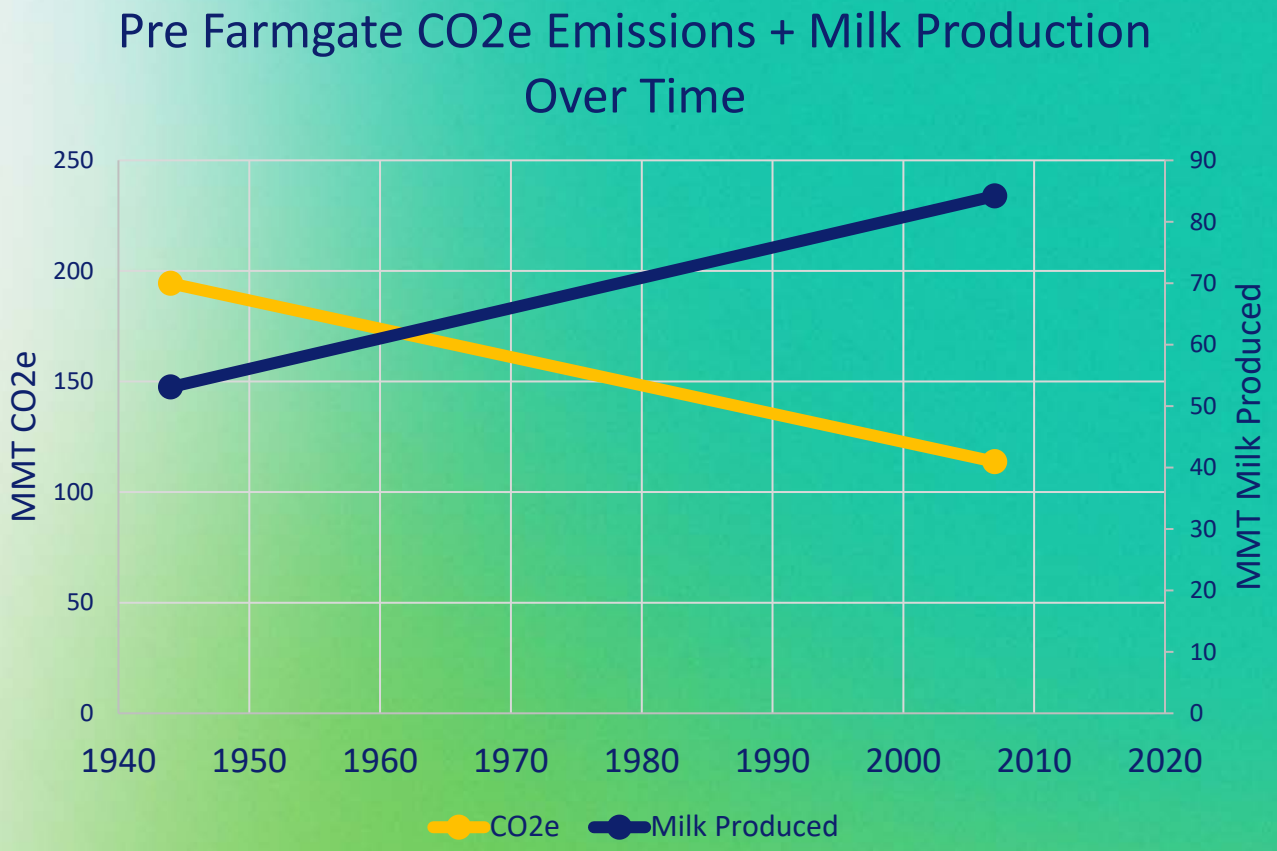
All for less than 2% of all US Greenhouse Gas Emissions

And We've Made A Lot Of Progress…



2009 J. L. Capper, R. A. Cady, and D. E. Bauman

And We've Made A Lot Of Progress…

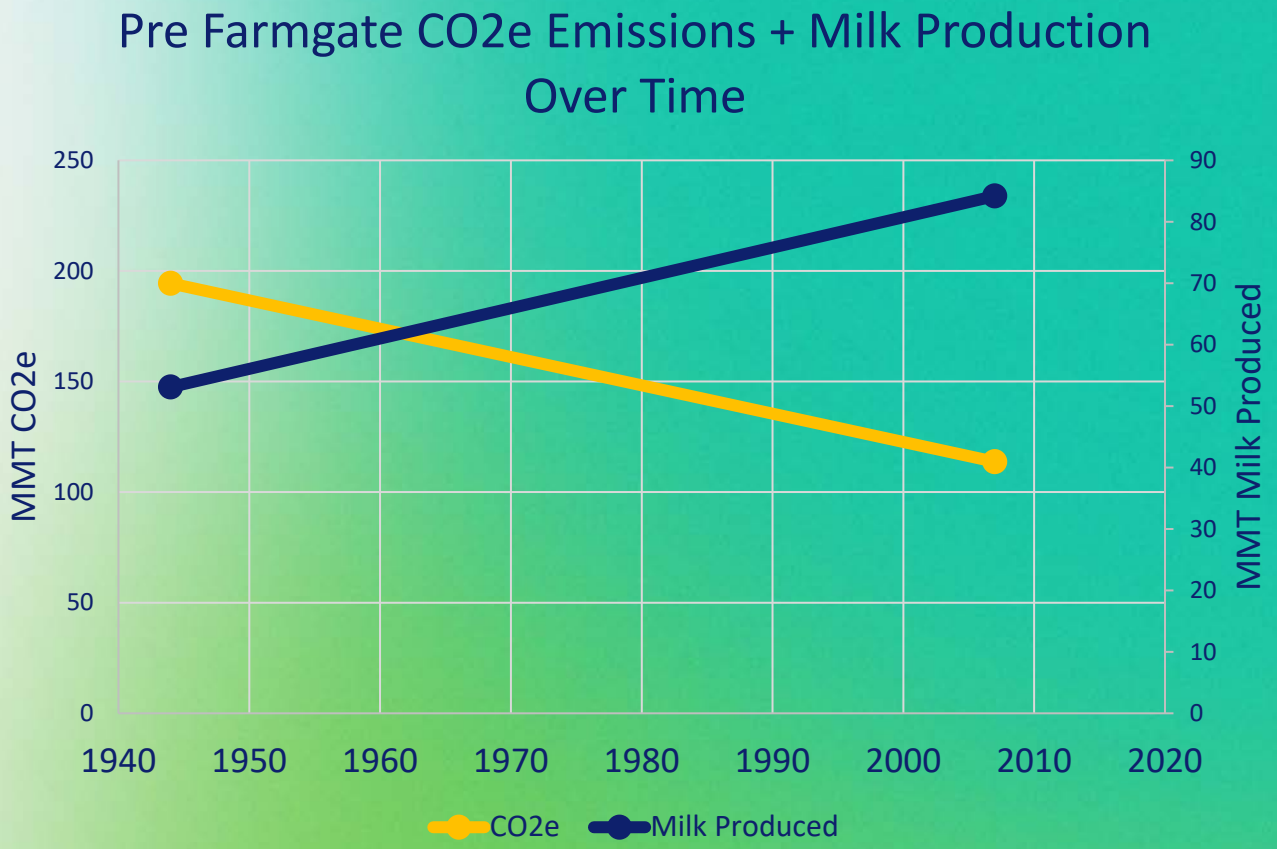


This additional milk production meets the complete protein requirements of

82 million additional children

2009 J. L. Capper, R. A. Cady, and D. E. Bauman

And We've Made A Lot Of Progress…



This additional milk production meets the complete protein requirements of

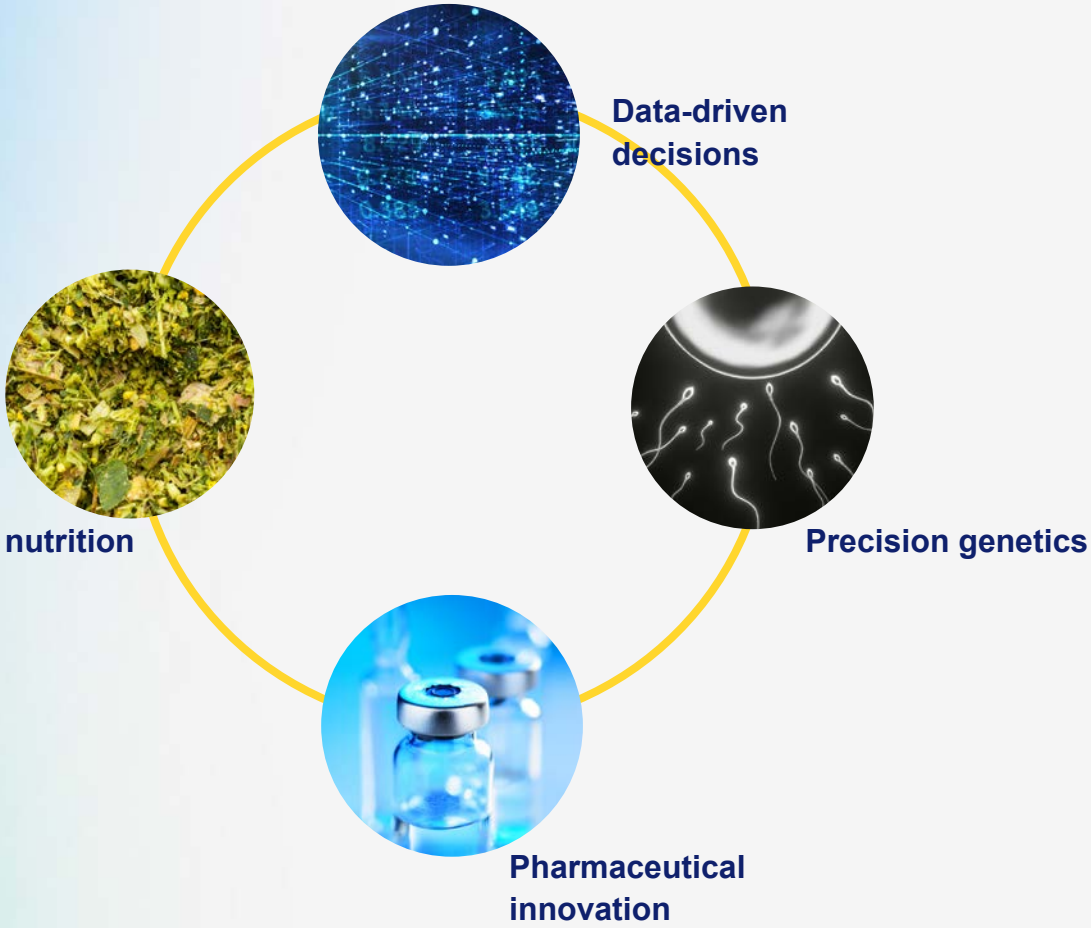
82 million additional children

While

reducing CO2e emissions 37%

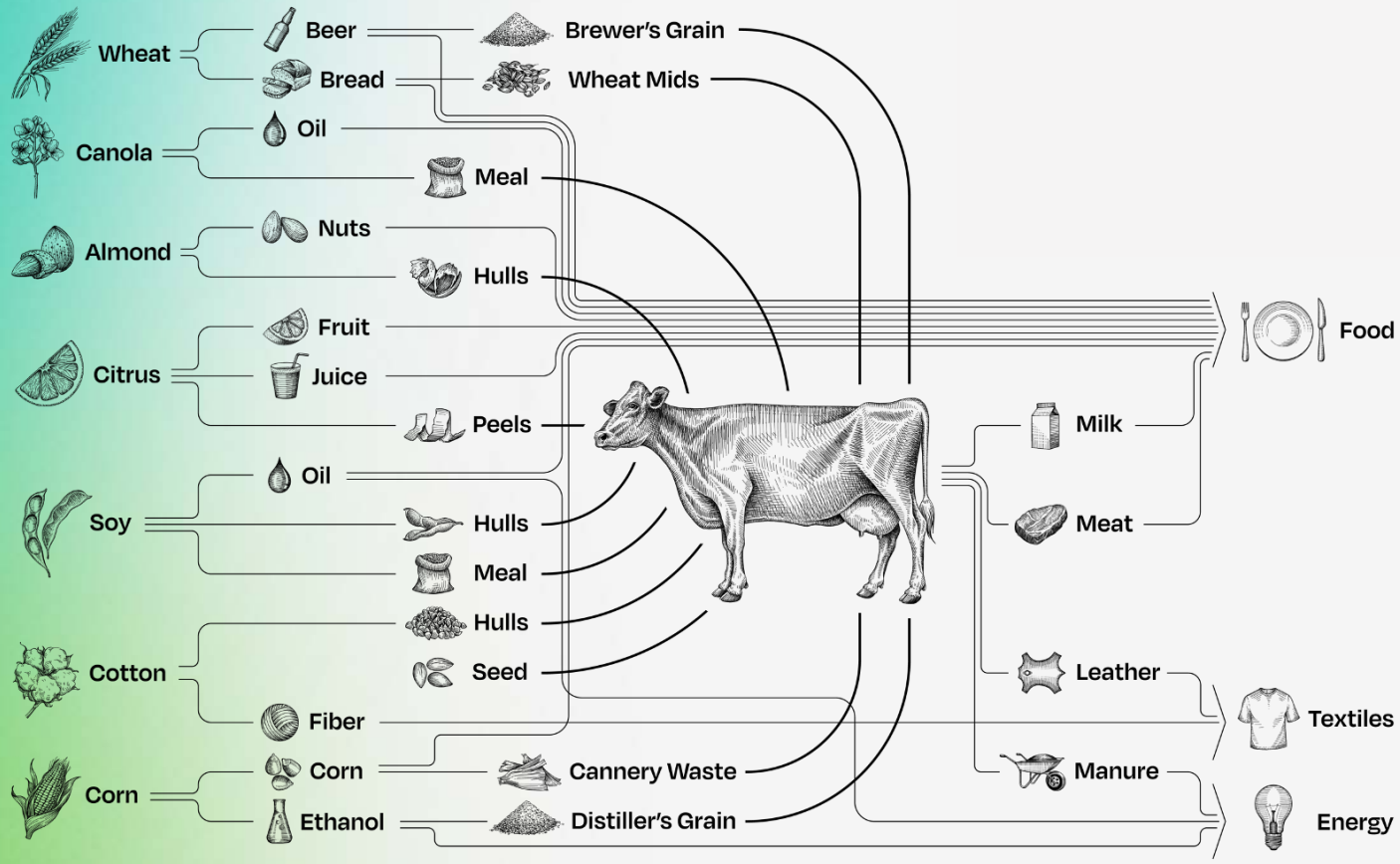
2009 J. L. Capper, R. A. Cady, and D. E. Bauman

We’ve Achieved This With Innovative Technology Adoption...



We've also reframed cows as a solution

The same microbes that lead to CH4 emissions enable cows to upcycle food waste



To Put This In Perspective....

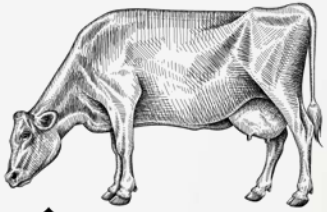
New York City is home to **8.3** million people

Every year, these 8.3 million New Yorkers throw away

9.2 billon pounds of food waste

If you multiplied New York City's food waste by **6X**, that would be

54 billon pounds of food waste



This is the same weight of food waste that US dairy cows upcycle every year into...

...the complete protein requirements of **58** million people

or **7X** the population of New York City

When cows upcycle this food, they prevent **83.8** million metric tons of CO_2e from entering the atmosphere, compared to sending the food waste to a landfill

This is **2X** the amount of emissions of all New York City's motor vehicle emissions combined

But We Have More To Do...

Cradle to Processor Gate

~187 MMT CO2e

But We Have More To Do...

But We Have More To Do...

Cradle to Processor Gate

~187 MMT CO2e

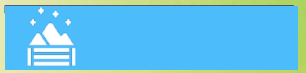
Cradle to Farm Gate

~140 MMT CO2e

Feed - 30%

Enteric - 30%

Manure - 30%



Fuel - 10%

But We Have More To Do...

Cradle to Processor Gate

~187 MMT CO_2e

Cradle to Farm Gate

~140 MMT CO_2e

Feed - 30%

Enteric - 30%

Manure - 30%

Fuel - 10%

Projected Gap After All Existing Tech Deployed

~30-100 MMT CO_2e

... So We Made An Inventory Of Opportunities...

Feed Production and Storage

Soil Sequestration				Nutrient Application								Non-nutrient Inputs				Feed Loss from Storage & Transport		
				Manure				Synthetic										
Tillage	Cover Crops	Alfalfa	Grazed	Source	Place	Time	Rate	Source	Place	Time	Rate	Field Ops Energy.	Irrig. Energy	Herb/ Pest -icides	Alt fuel	Wind breaks	Feed Center	Bins vs Bays

Enteric Emissions

Ration Balancing				Selective Breeding	Productive Life		
Forage	Additives	Fat Feeding	Starch Feeding	Use of Index	Adult Herd Health	Youngstock health	Repro

Manure Emissions

Manure Comp.	Manure Storage + Mgmt			Composting*				Coarse Solid/ Liquid Separation				Advanced Treatment (Fine Solid Separation)				Biogas Collection + Utilization	
								No Separ- ation	Separation								
Nitrogen Excretion	Storage Interval	Acidifica- tion	Flush to Scrape	Static/ Stacking	Windrow	Turning/ Drum	Silo		Screw Press	Rotary Screen	Slope Screen	Chem Flocc + Dewater	Centrifuge + Screen	EMVR (Varcor)	Vermilifil - tration	Anaerobic digester	Cover + Flare

Energy Emissions

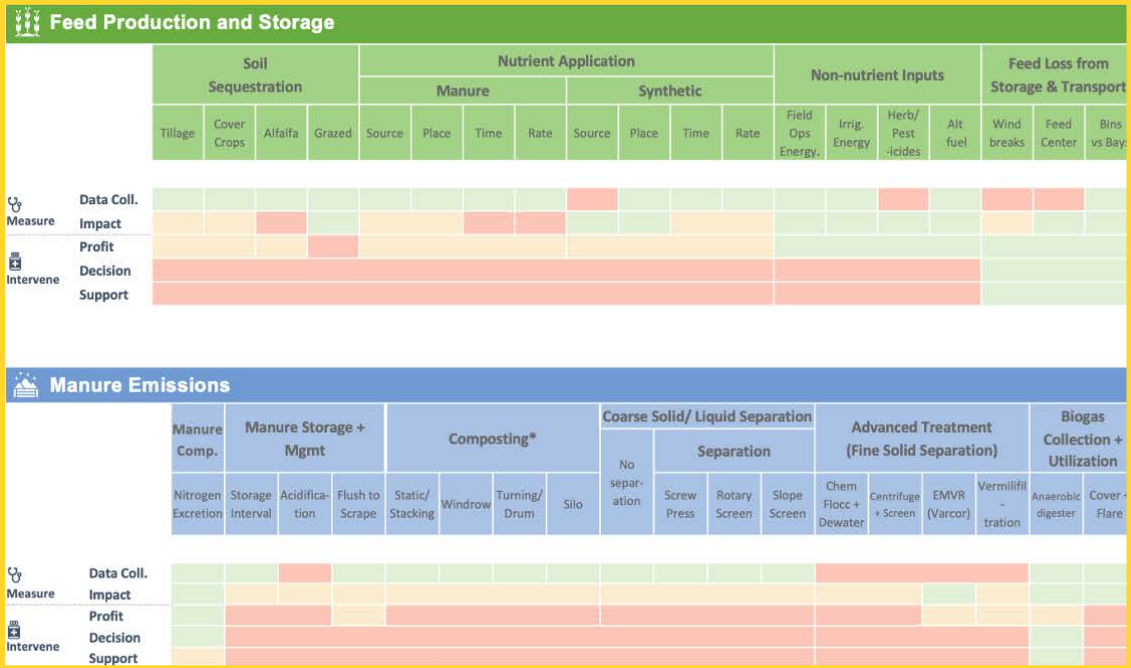
Electricity				Fuel Use			
Energy Mix		Energy Saving Upgrades					
Energy mix from Grid	Solar/Wind /Digester On Farm	LED	Plate Coolers	Diesel	Biodiesel	Oil	Gasoline

...Created A Rubric...

Category	Parameter
Measurement Ability to accurately collect and report	**Data Collection** • Can industry collect data on this today? • Is Checkoff able to have access to aggregated, anonymized data? **Quantified Impact** • Is there respected literature that shows the magnitude of emissions reductions due to practice/technology?
Intervention Ability to change practice on farm	**Profit Model** • Is there a compelling financial case for the producer to implement this practice? **Decision Tool** • Is there a tool accessible to producers and trusted advisors that shows impact, cost, feasibility, and tradeoffs of choices? **Support Network** • Is there a support network? • Is the producer's support network activated?

...And Assessed Their Readiness....

...And We See A Lot Of Opportunity At The Intersection Of Poop And Crop Production



Announcing

The PoopShot

A CSU Ag Innovation Center Initiative to ensure our food and energy systems get the most out of ruminant manure

PoopShot Seeks To Valorize Manure To Decarbonize Beef and Dairy

Do you know something/someone that can help me in this journey?

Jordan Kraft Lambert
Director of Ag Innovation,
College of Ag Sciences, CSU Spur

Message me your thoughts on LinkedIn!

SESSION 1

Hard-to-Decarbonize Industries

Day 1: 10:15 a.m.–1:15 p.m.

Ana Aday

Researcher
NREL Building Technologies and Science Center

NREL
Transforming ENERGY

Breaking the Mold: Why is Decarbonizing Cement and Concrete Hard?

Ana Aday
NREL Building Technologies and Science Center, Researcher

The Triple Planetary Crisis

The **triple planetary crisis** refers to the three main issues that humanity currently faces, reinforcing one another and driving further damage. Each must be resolved for us to have a viable future on this planet.

Pollution

- Air pollution is the largest cause of **disease and premature death** in the world
- Pollution is one of the main drivers of **biodiversity loss and climate change**
- **Industrial Decarbonization** can *reduce pollution* for the construction industry

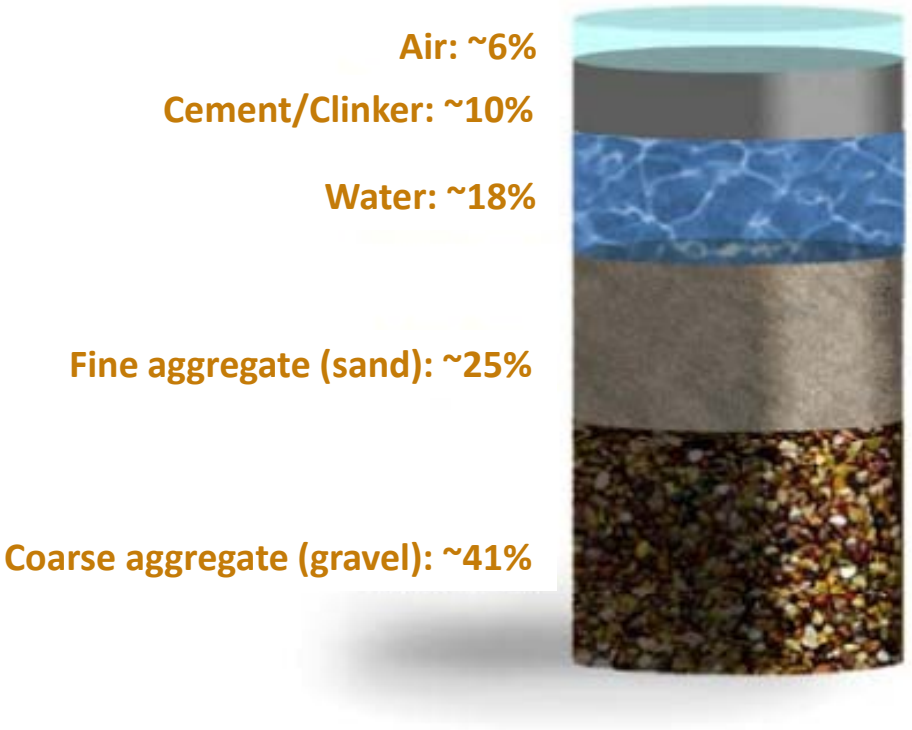
Photo from iStock-1320345376

What is the difference between cement and concrete?

Photo by Jk Cement

Cement and Concrete

- Concrete is 2nd most consumed material globally (after water)
- Comprised of three main ingredients:
  - Cement, aggregate, water
- Cement is the binder that holds aggregate together
- Cement powder is produced from ground clinker



Our Challenges and Opportunities

Decarbonization

- Requires lowering carbon intensity of electricity generation, **substituting electricity for fossil fuels**
- Calls for combination of **renewable energy and diverse energy storage**
- **Requires new technologies** for cement, steel, ammonia, ethylene industries

Societal Demand for Cement and Concrete by the Numbers

20 B m^3

Volume of concrete needed to accommodate global population growth by 2050

3.8 Gt

Assuming current practices **CO_2 emissions** due to **cement manufacturing**

By 2050

417.06 ppm

Global average **atmospheric concentration of carbon dioxide** (CO_2) in 2022, a record high

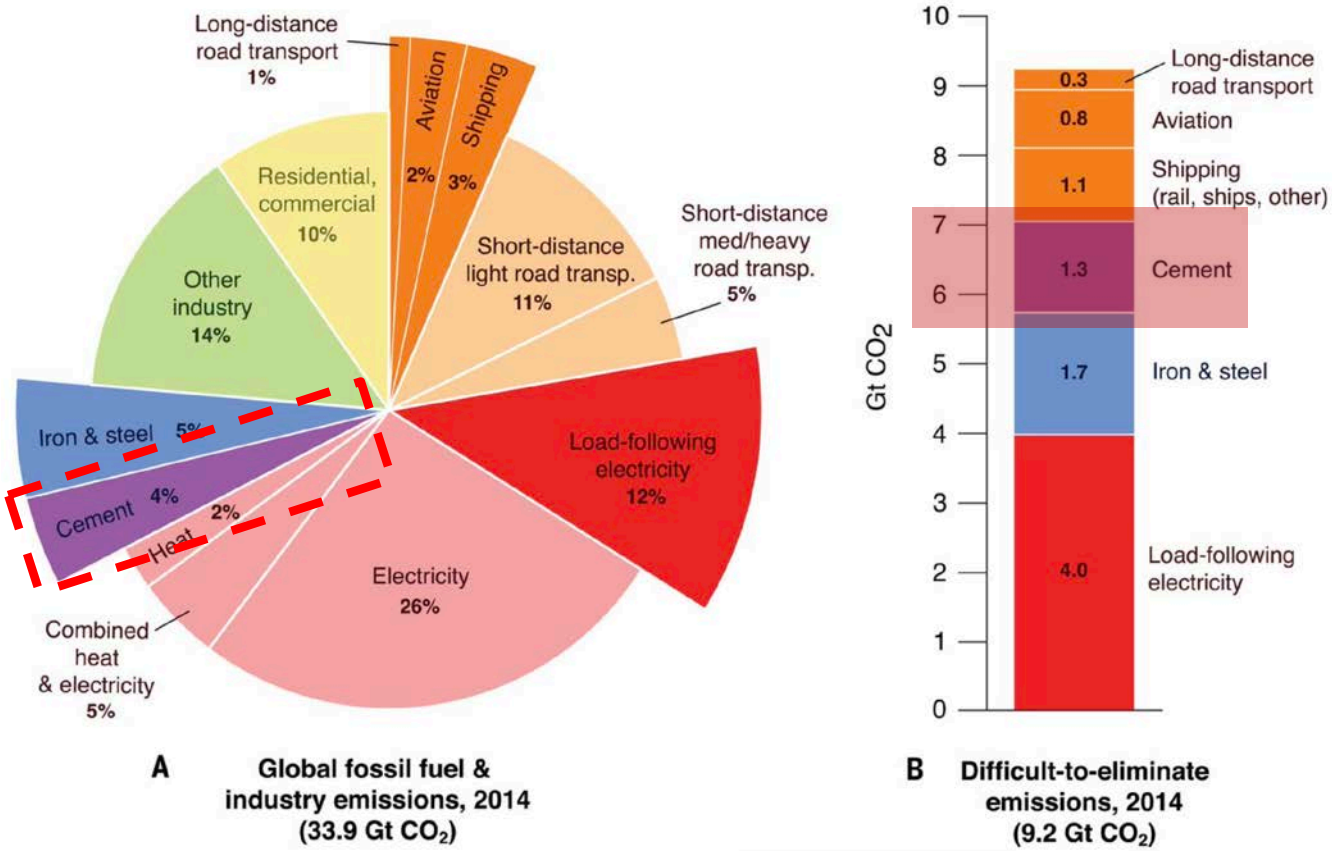
85%

Of the **CO_2 emissions** from the **manufacturing of the clinker,** intrinsic to the material

100 M

Tons of **cement** produced annually

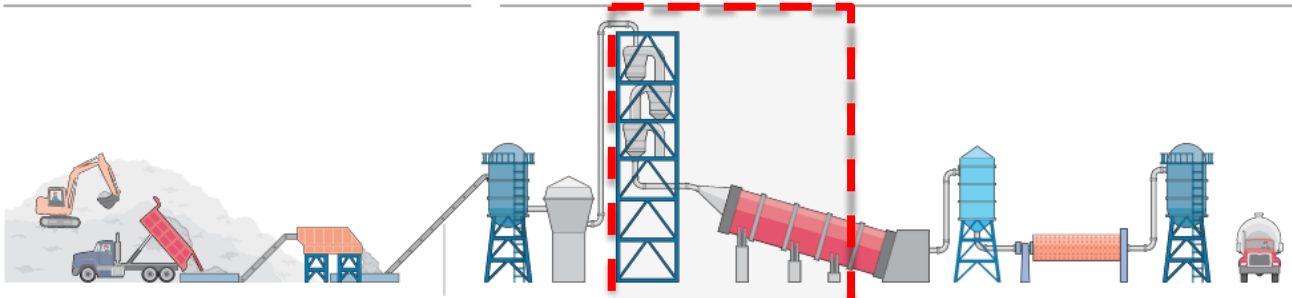
Cement is a ‘Hard-2-Decarbonize’ Sector



Davis, Steven J., et al. "Net-zero emissions energy systems." *Science* 360.6396 (2018).

Cement Energy and CO_2 Emissions Landscape

Raw materials, energy, and resources | **Clinker and cement manufacturing**

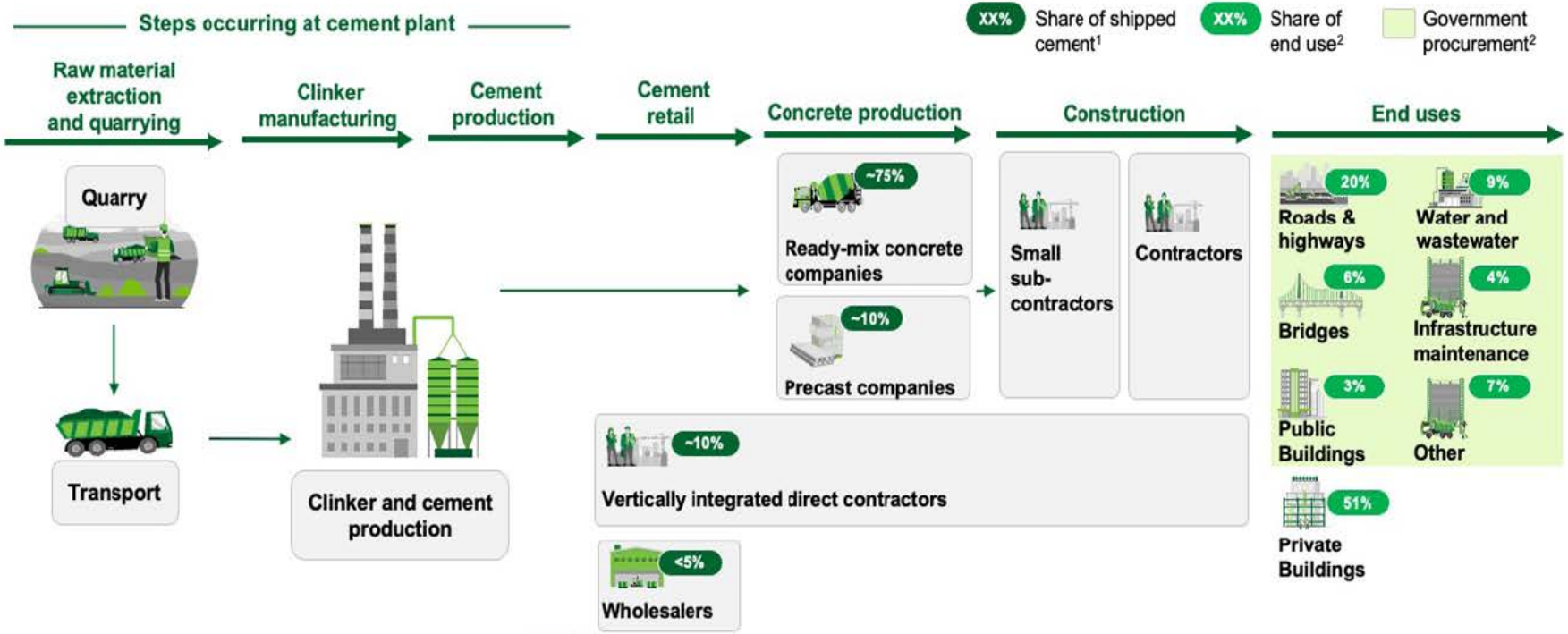


	Quarry	Crusher	Transport[1]	Raw mill	Kiln and preheater/ precalcinator[2]		Cooler[3]	Cement mill	Logis-tics[4]	**Total**
Energy, mega-joule/ton	40	5	40	100	3,150		160	285	115	3,895
CO_2, kilogram/ton	3	1	7	17	479 Calcination process	319 Fossil fuels	28	49	22	925

86%

Source: McKinsey

[1]Assumed with 1kWh/t/100m.
[2]Assumed global average, data from the Global Cement and Concrete Association, Getting the Numbers Right 2017.
[3]Assumed reciprocating grate cooler with 5kWh/t clinker.
[4]Assumed lorry transportation for average 200km.



Cement Production in the Construction Value Chain

Source: Pathways to Commercial Liftoff: Low-Carbon Cement, 2023

Building Challenges

- The U.S. building stock consists of more than **100 million buildings** and over **300 billion square feet.**[1]
- Approximately **half** of the building stock (55% of homes and 46% of commercial) were built **over 40 years ago.**[2]
- **75% of today's buildings** will still be in operation **in 2050**. [3]

Image by NREL/39565

Image by NREL/53355

Sources: 1) U.S. EIA Annual Energy Outlook 2021. 2) U.S. EIA CBECS 2018 and RECS 2015.
3) Guidehouse Insights. Global Building Stock Database 4Q20.

Why now?

- Business as usual will not achieve the 2050 climate goals.
- Scale-up of decarbonization technologies in cement will have broad impacts to benefit the economy, environmental quality, and health of local communities.
- We are in an unprecedented and promising era, immense potential for significant impact in the concrete and cement industry.
- This is driven by the pressing need to meet global infrastructure demand in a fair and equitable manner.

Photo by Werner Slocum / NREL

Photo by Bryan Bechtold / NREL

Our Challenges and Opportunities

Standard and Certifications

- Prescriptive vs performance-based standards
- Implementing new and modified standards
- Quantification of embodied carbon

Image: Ana Aday/NREL

Image: Ana Aday/NREL

Prescriptive vs. Performance Based Standards

- Prescriptive
  - Defines a concrete mixture in terms of its constituents and their relative proportions
  - Most often used in practice
- Performance
  - Defines a concrete mixture by measurable fresh and hardened properties that will satisfy certain performance criteria

- ACI 318-Building Code for Structural Concrete
- ASTM C150 and C595
  - Cements and blended cements (prescriptive)
- ASTM C1157
  - 1st performance standard for cement

Quantification of embodied carbon

Product Category Rules (PCRs)

- The set of guidelines that determine how the data is gathers and evaluated with performing the LCA

Environmental Product Declarations (EPDs)

- Consists of the final LCA report and summary as verified by a 3rd party

Regulatory Landscape

- Extensive capital cost investments
- State/Federal reporting
- Policy models for cost increases
- Accelerated adoption of low-carbon materials

Deep Decarbonization May Require Extensive Capital Cost Increases

- **Cement plants can cost several hundreds of millions, even exceeding $1B**
- **Plants are expected to operate for 50-100 years**
- **Permits are costly and time prohibitive for an unrealistic for fast decarbonization**
  - New Source Review (NSR) program
  - Clean Air Act (CAA)
  - EPA
  - National Environmental Policy Act (NEPA) regulations
  - Clean Water Act (CWA), and state standards

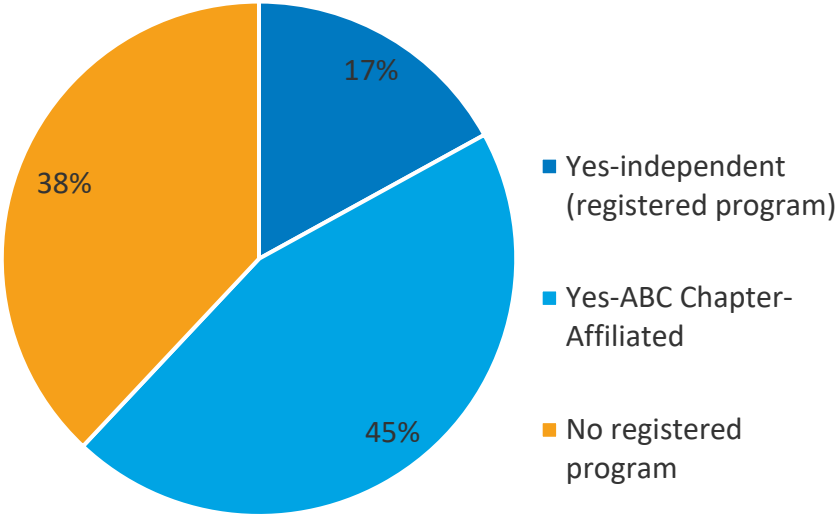
Solutions to Deep Decarbonization Costs

- Establish policy models that can offset cost increases
- Coordinated procurement for long-term premiums
- Updated construction regulations that require utilization of low carbon materials in projects
- DOE has ~$1.2.B in funding to accelerate the adoption at the state and local level of traditional and innovative building energy codes

Workforce Development

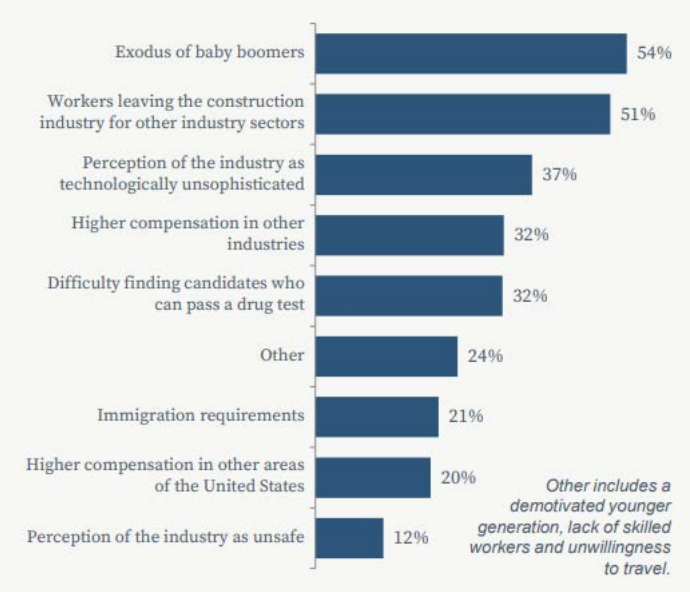
- Labor shortage comes down to qualifications
- Diversity in the built environment
- Better incentives and conditions
- Attracting a qualified workforce requires long term planning

Companies that have a State/Federal Department of Labor validated apprenticeship program



2023 American Builders and Contractors (ABC) Survey

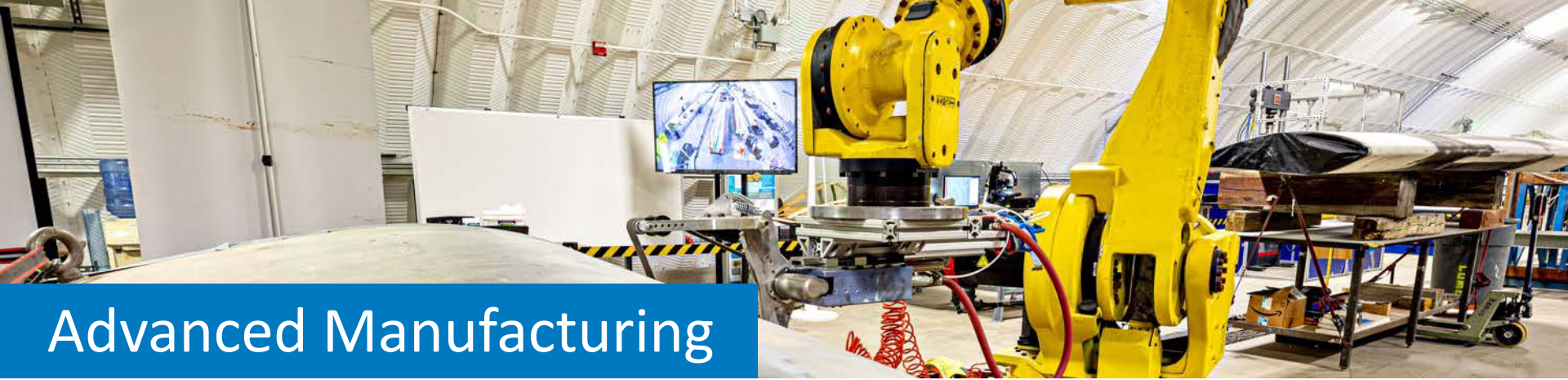
Factors that increased severity of skilled labor shortage (2022 poll)



$1.5B of total workforce education investment made by contractors in 2022

- Safety education holds 59% of workforce investment
- 8% of payroll on average is invested on workforce development
- 15% women in craft/trade roles

Breaking the Mold



Advanced Manufacturing

Develop advanced materials and manufacturing processes that drive improvements in **industrial energy efficiency and decarbonization**.

What's Next

- Completing supply chain, cost, and process analyses that enable decarbonization technologies to meet aggressive carbon-reduction goals and ensure that the U.S. manufacturing industry is competitive
- Creating novel manufacturing pathways for products that drive a decarbonized energy future and use a highly trained and diverse domestic workforce

Successes

- Demonstrated the effectiveness of silicon carbide power electronics devices that enable higher levels of distributed energy resources while reducing energy storage requirements.

Photo by Werner Slocum, NREL, 65144

Future Directions for NREL Construction Industry Decarbonization

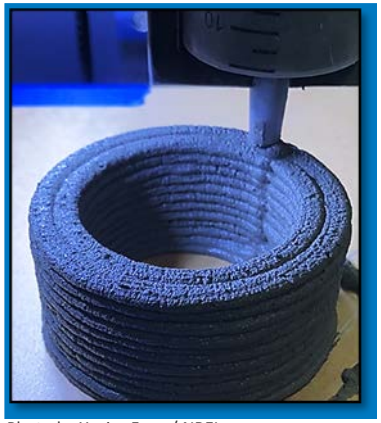


Photo by Xavier Fross/ NREL

Implementing novel approaches for materials deployment with efficient construction processes.

NREL can play an important role in engagement with the industry and provide a platform for de-risking initial stages of technology development

Photo by Lindsey McGuirk/ NREL

Photo by Ana Aday/ NREL

Development and adoption of low carbon construction materials and to address energy requirements of residential and commercial buildings.

Convening industry leaders and NREL expertise in industrial decarbonization

Photo by Joe DelNero / NREL

Thank You!

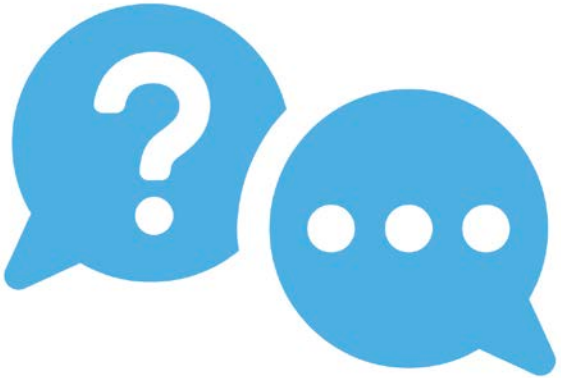
www.nrel.gov

Photo from iStock-627281636

SESSION 1

Hard-to-Decarbonize Industries

Day 1: 10:15 a.m.–1:15 p.m.



Moderated Q&A

Audience Feedback

Please **follow the link or QR code** below to answer the **first four** audience poll **questions**.

Go to

www.menti.com

Enter the code

6948 5694

Or use QR code

SESSION 1

Hard-to-Decarbonize Industries

Day 1: 10:15 a.m.–1:15 p.m.

Rolf Weberg

Executive Director
Natural Resources Research Institute, University of Minnesota Duluth

The Energy Transition and the Opportunities for Integrated Industrial Decarbonization

R.T. Weberg
rtweberg@d.umn.edu

Natural Resources Research Institute
University of Minnesota Duluth
Driven to Discover®

NRRI Delivery: Strategic Initiatives

Accelerating Industrial Decarbonization

Dr. Jen King

National Renewable Energy Laboratory

Jennifer.king@nrel.gov

The Challenge Ahead

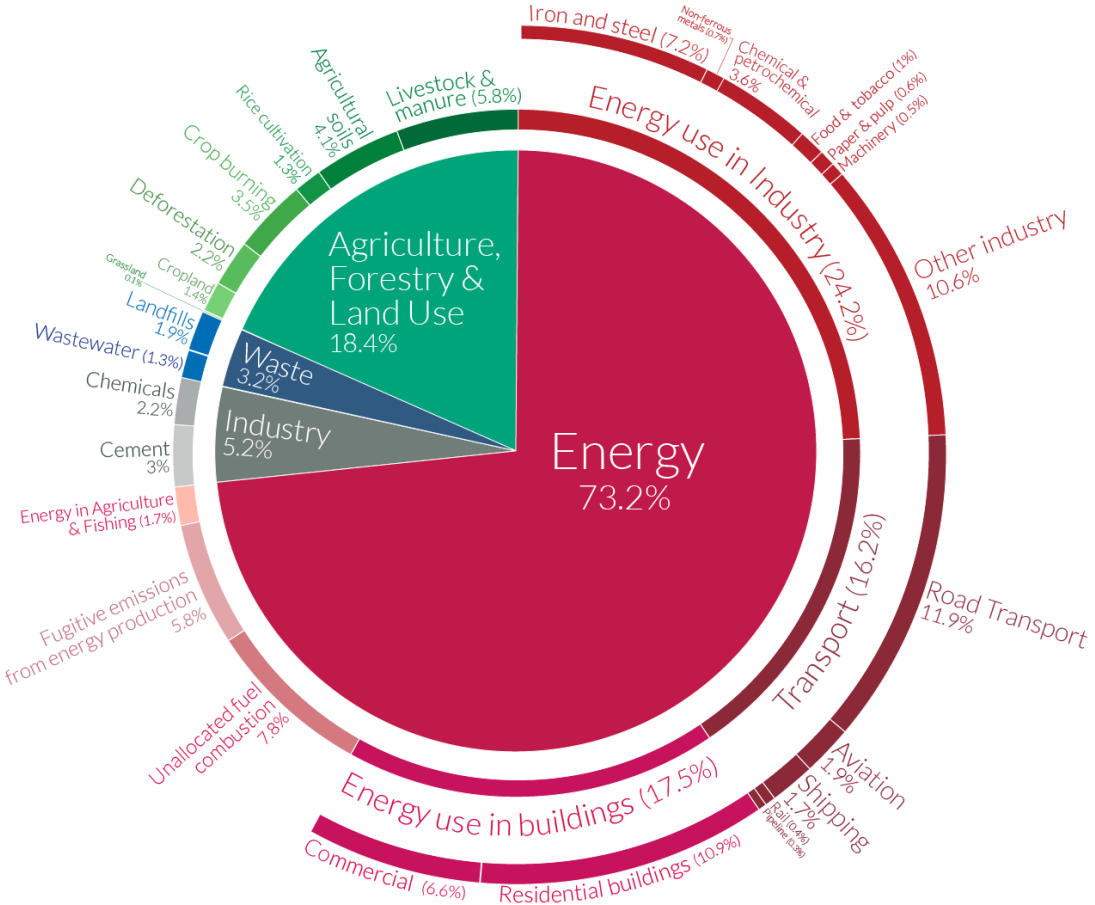
How do we support sound, long-term decisions to sustain life as we know it…

while creating opportunity and reducing risk?

Global greenhouse gas emissions by sector

This is shown for the year 2016 – global greenhouse gas emissions were 49.4 billion tonnes CO_2eq.

Our World in Data



OurWorldinData.org – Research and data to make progress against the world's largest problems.
Source: Climate Watch, the World Resources Institute (2020).

Licensed under CC-BY by the author Hannah Ritchie (2020).

Driver

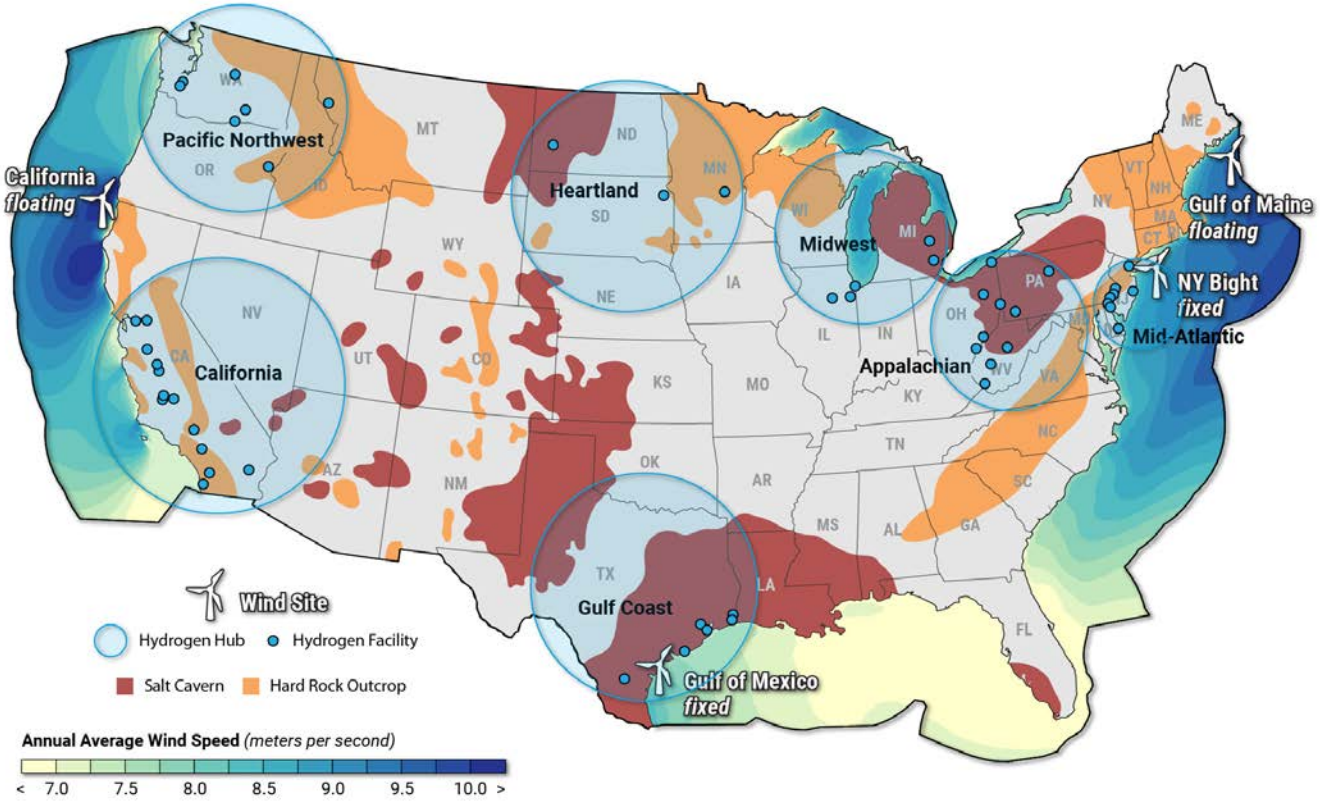
Energy Transition

Goal

Industrial

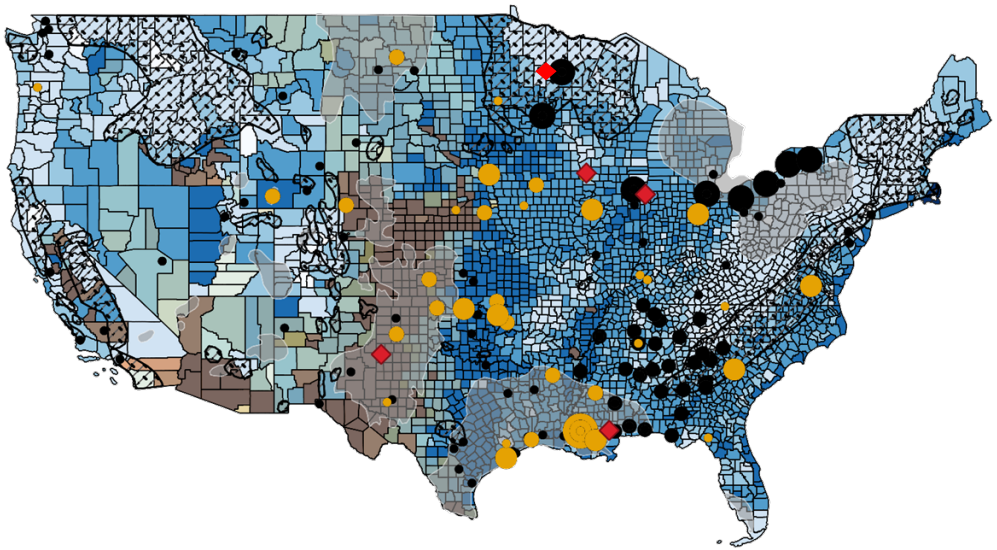
Decarbonization

Hydrogen Hubs



DOE Study: Locations for Green Steel

collaboration of 5 National Laboratories



Legend

- Selected Locations

Hydrogen Demand for Ammonia Production (MT)
- 0 - 35,000
- 35,000 - 110,000
- 110,000 - 250,000
- 600,000 - 810,000

Hydrogen Demand for Synfuels and Metals (MT)
- 0 - 1,000
- 1,000 - 50,000
- 150,000 - 700,000
- Hardrocks
- Salt Caverns

Water scarcity index (-)
- 0 - 5
- 5 - 10
- 10 - 30
- 30 - 50
- 50 - 70
- 70 - 100

H2 Potential from Solar and Wind (MT/km2)
- 0 - 10
- 10 - 250
- 250 - 500
- 500 - 1,000
- 1,000 - 5,000
- 5,000 - 95,000

DOE CHECKPOINTS

- ❑ Source of "Green Electrons"
- ❑ Potential for hydrogen storage
- ❑ Resources (iron ore, water, etc.)
- ❑ Infrastructure

STATES UNDER CONSIDERATION

WYOMING
IOWA
INDIANA
TEXAS
MISSISSIPPI

Day Tripper of Duluth

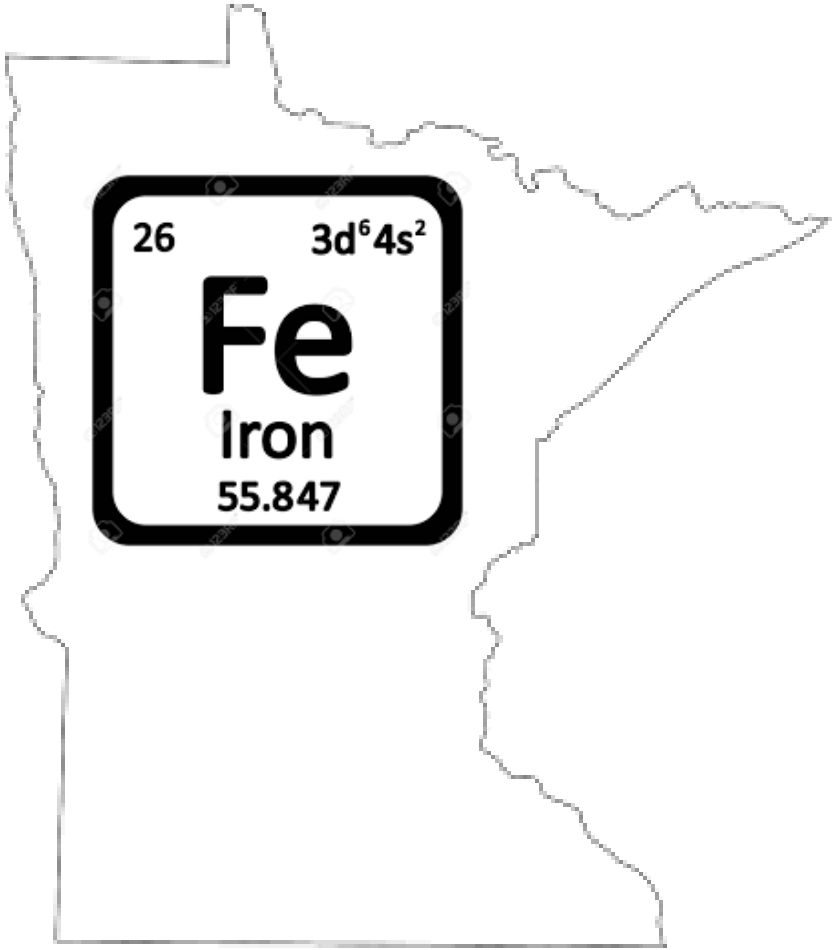
Duluth News Tribune

Duluth News Tribune

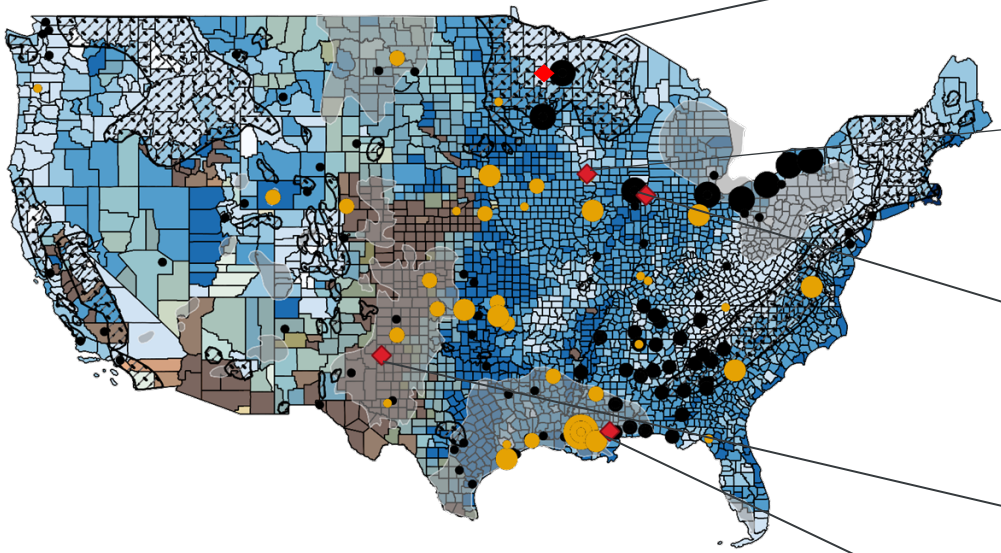
In Forum

Mining Artifacts

Welcome to Iron



DOE Study: Locations for Green Steel, cont.



MINNESOTA
- Suitable renewables
- Lined rock caverns; raw materials
- Infrastructure

IOWA
- Existing ammonia pipeline
- Close to ammonia and steel demand centers
- No geologic storage

INDIANA
- Largest steel mill in the U.S. with 8.2 MMT steel/year capacity
- No geologic storage

TEXAS
- Salt caverns and water stress region
- Excellent wind resources

MISSISSIPPI
- Close to existing demand
- Salt caverns

Legend

- Selected Locations

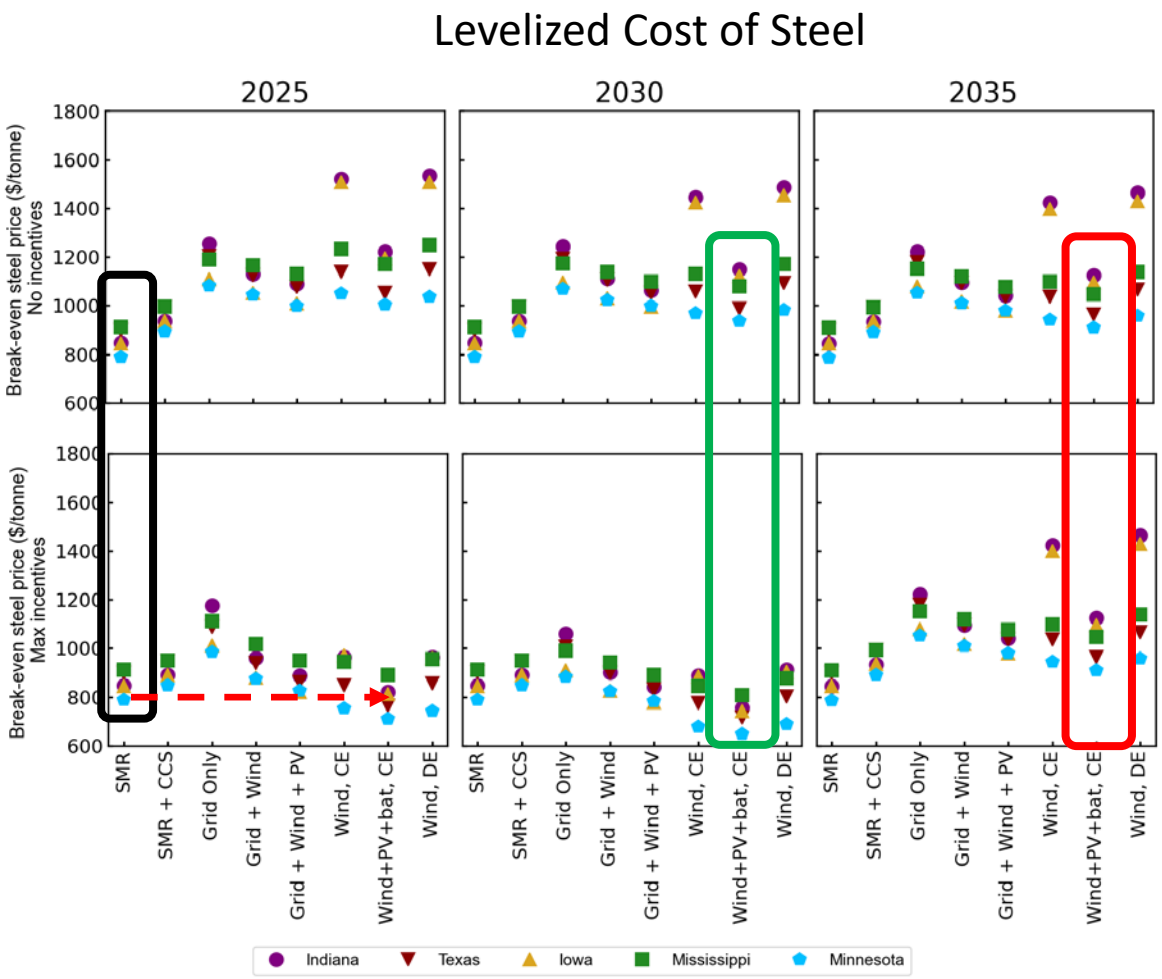
Hydrogen Demand for Ammonia Production (MT)
- 0 - 35,000
- 35,000 - 110,000
- 110,000 - 250,000
- 600,000 - 810,000

Hydrogen Demand for Synfuels and Metals (MT)
- 0 - 1,000
- 1,000 - 50,000
- 150,000 - 700,000
- Hardrocks
- Salt Caverns

Water scarcity index (-)
- 0 - 5
- 5 - 10
- 10 - 30
- 30 - 50
- 50 - 70
- 70 - 100

H2 Potential from Solar and Wind (MT/km2)
- 0 - 10
- 10 - 250
- 250 - 500
- 500 - 1,000
- 1,000 - 5,000
- 5,000 - 95,000

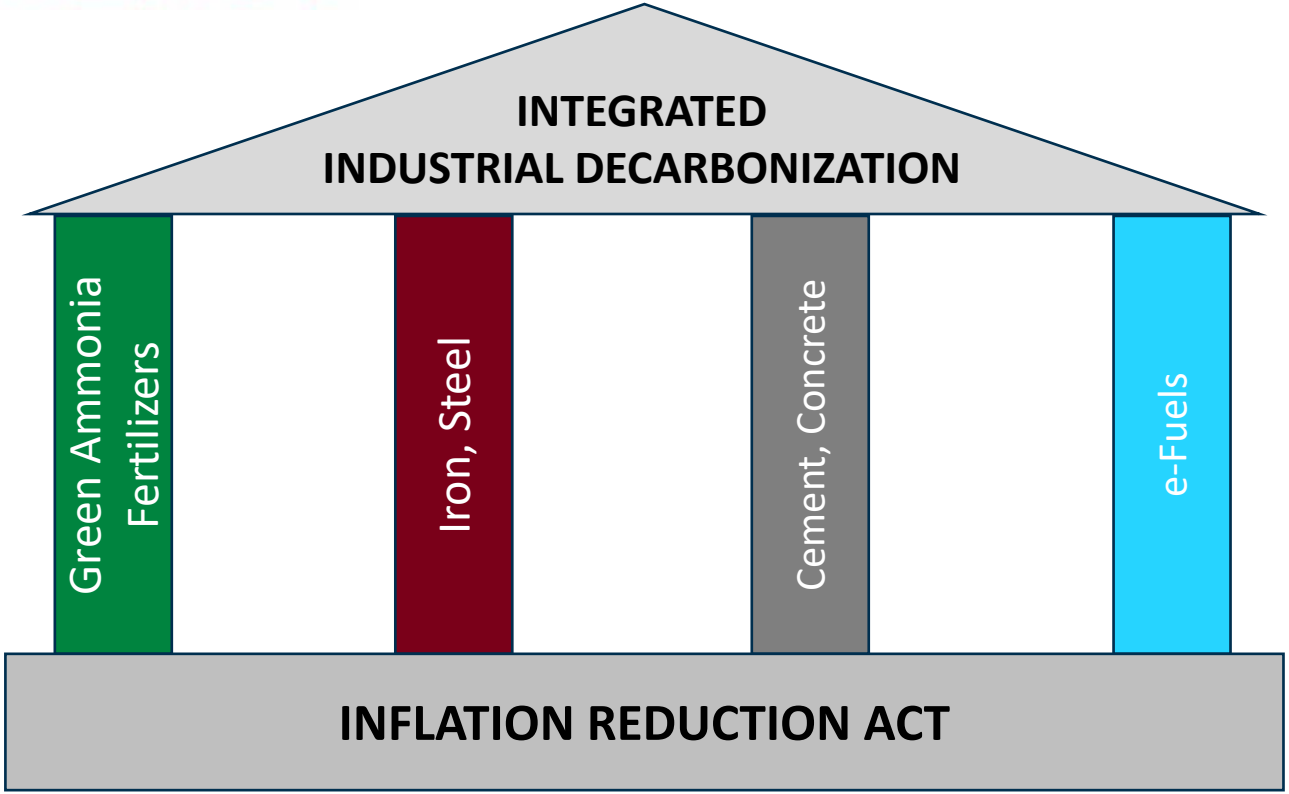
The IRA is a *Game-Changer* with a *Sense of Urgency*



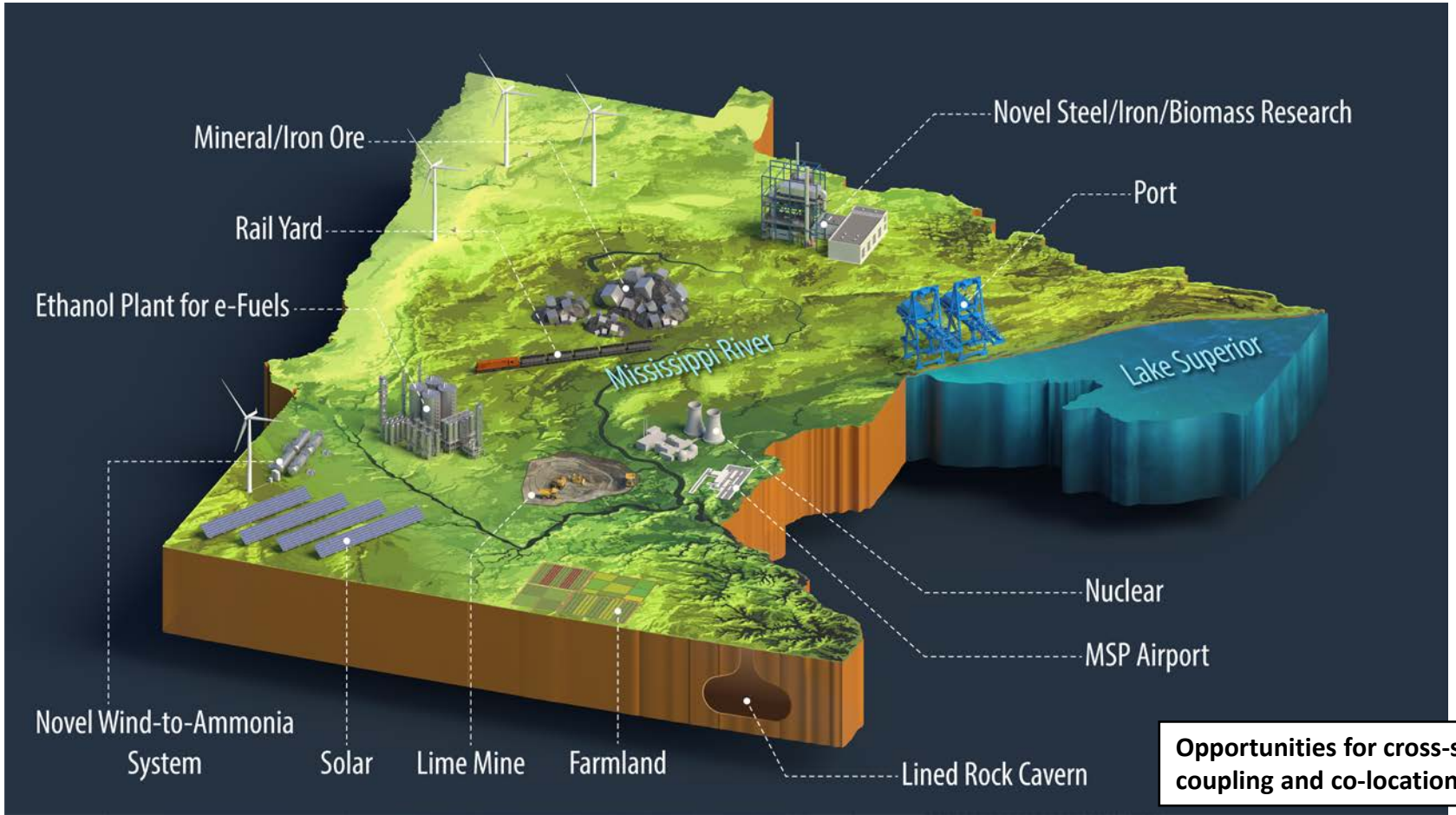
No IRA

With IRA

U.S. DEPARTMENT OF ENERGY



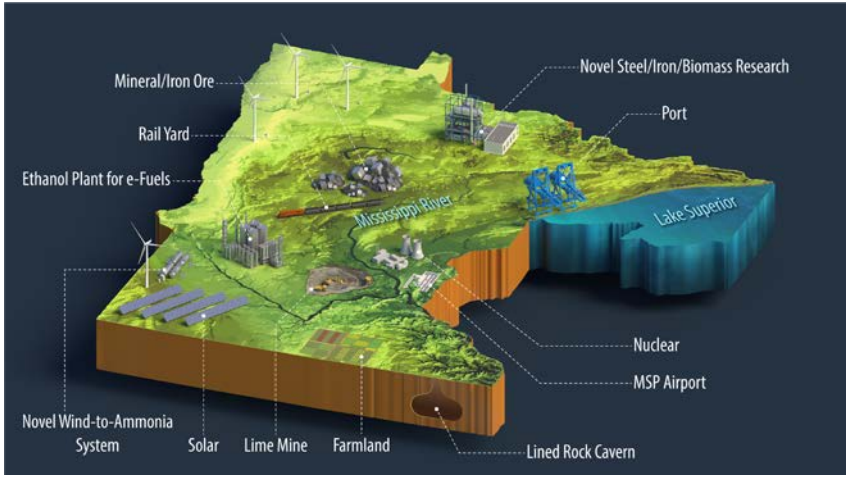
Minnesota: ALL the Key Attributes



Opportunities for cross-sector coupling and co-location

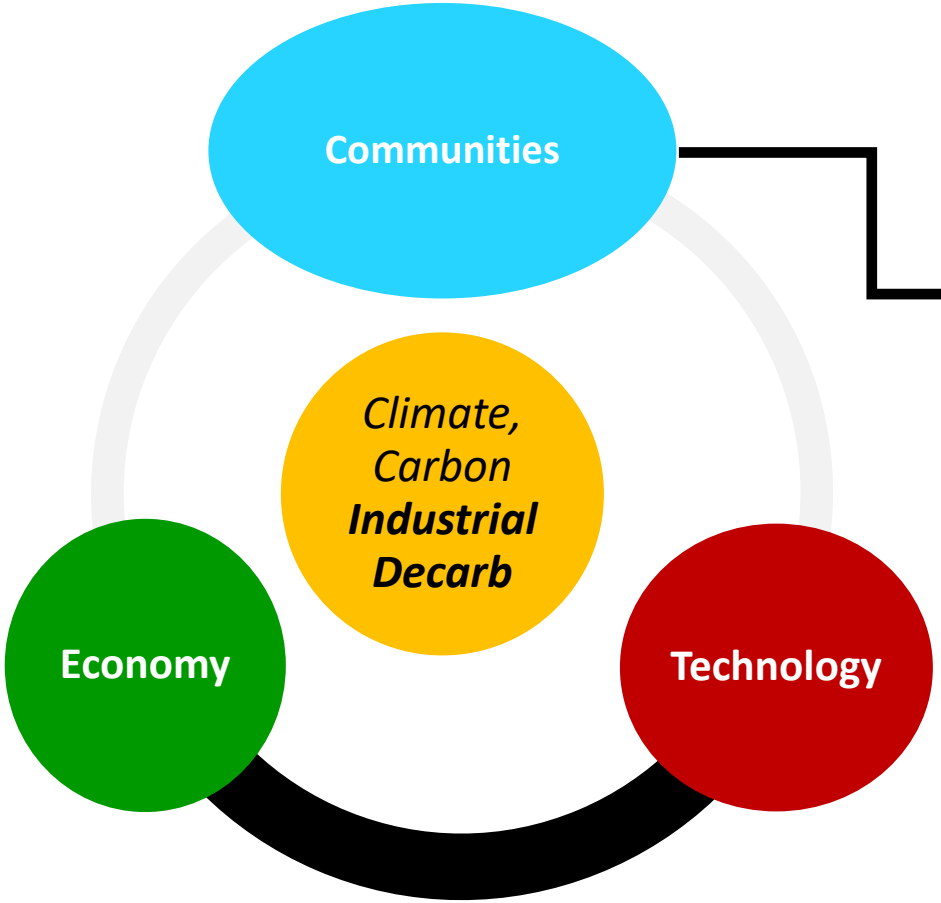
Minnesota's Opportunity

- ✓ MN occupies a *unique* position with key assets co-located in-state
  - Resources
  - Infrastructure, shipping
  - Renewable Energy
  - Storage
  - Industry & Business
  - Governments, Agencies
  - Communities
  - Academia & Research
  - NGO's



- ✓ The IRA provides a finite window of opportunity (2035)
- ✓ Requires the "**Minnesota Community**" to own it

The Three Lenses of Success (EJ40)



Environmental/Social Justice

- Tribal Governments
- Disadvantaged Communities
- Marginalized Communities
- Rural vs. Urban
- Business & Industry
- Agriculture
- NGOs
- State/Local Governments
- State/Federal Agencies
- Healthcare
- Education/Workforce
- Housing/Childcare
- More…

Lessons of Engagement

- ✓ Regional interrelationships need to be understood and respected. Be willing to backtrack to stay on track
- ✓ Present the opportunities, not THE solution
- ✓ All stakeholders, particularly the disenfranchised, need to be actively engaged & respected *from the very beginning*
- ✓ Industry has a strategy,…and stockholders. Rapid responses can be challenging.
- ✓ Have contingency scenarios
- ✓ Be honest; be the learner
- ✓ Patience, Patience, Patience

Minnesota Iron & Steel Highlights

Today:

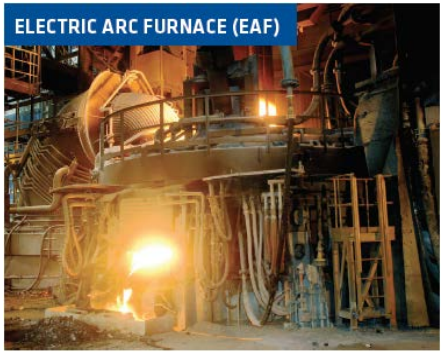
- National iron & steel industries engaged in CO_2 reduction
- Majority of Minnesota iron leaves as taconite pellets to serve blast furnace (BF/BOF) market

30% US Production

Tomorrow:

- Refined iron oxide/metallic iron products for BF/BOF *and* electric arc furnace (EAF) markets.
- Emerging ore-to-steel producers
- Industry decarbonization

70% US Production



Green Steel Scenarios

A) Blast furnace conversion to green hydrogen blending

- ➢ **MN role:** provide designed iron feedstocks

B) Green Iron Product(s) + Electric Arc Furnace

- DRI (direct reduced iron), HBI (hot briquetted iron), pig iron
- ➢ **MN role: produce green iron and/or steel products**

C) Conversion of Ore to Green Iron Units/Green Steel

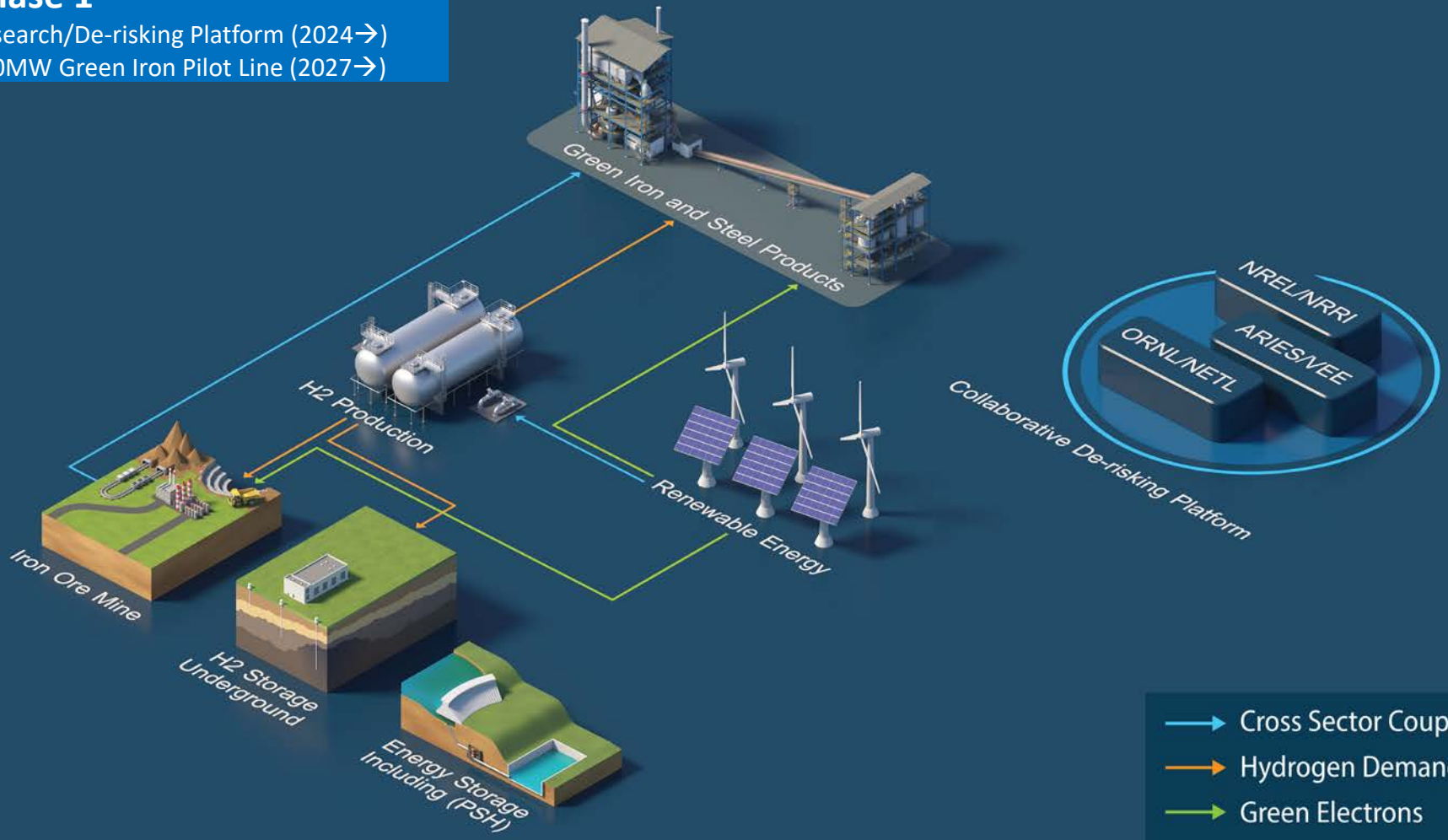
- Green energy with/without green hydrogen to convert ore to product
- Can utilize poor grade ores
- May be amenable to renewable power variability
- ➢ **MN role:** engage opportunities, support development
  - SSAB, H_2 Green Steel, others

Emerging Minnesota Execution Plan

1. **Minnesota Assessment & Planning**
   - 90 days: identify leader(s), engage stakeholders
2. **Research Effort – ongoing risk reduction**
   - 5MW H_2 generation
   - Collaboration: NREL, NRRI, National Labs
   - Initiating 2024
3. **Pilot Demonstration**
   - 100 MW H_2 generation
   - Targeting 2027 commissioning
   - Industry participation
4. **Full Demonstration**
   - 1 GW H_2 generation
   - Must be initiated by December 2032
   - Industry investment

Phase 1

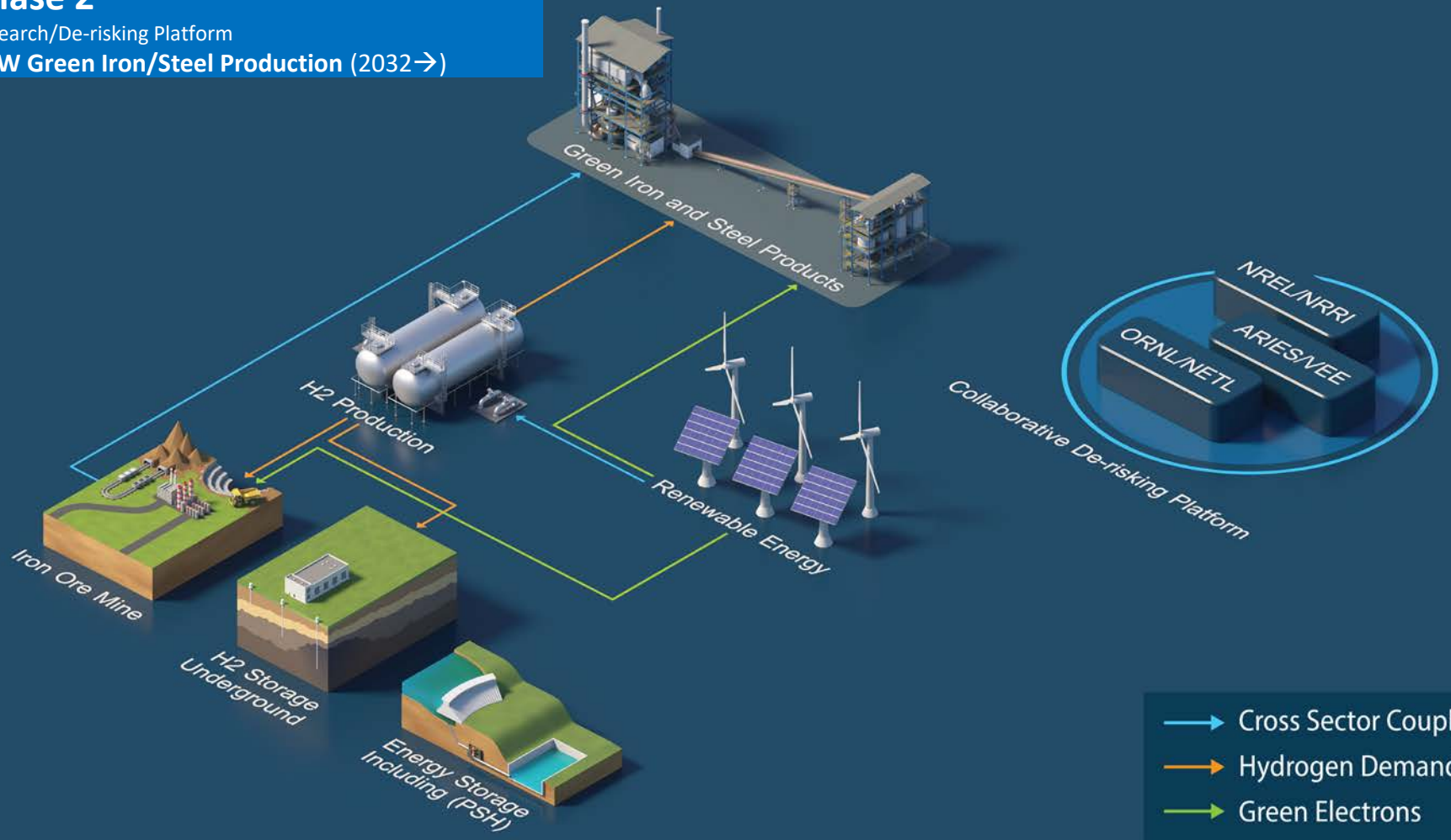
Research/De-risking Platform (2024→)
100MW Green Iron Pilot Line (2027→)



Phase 2

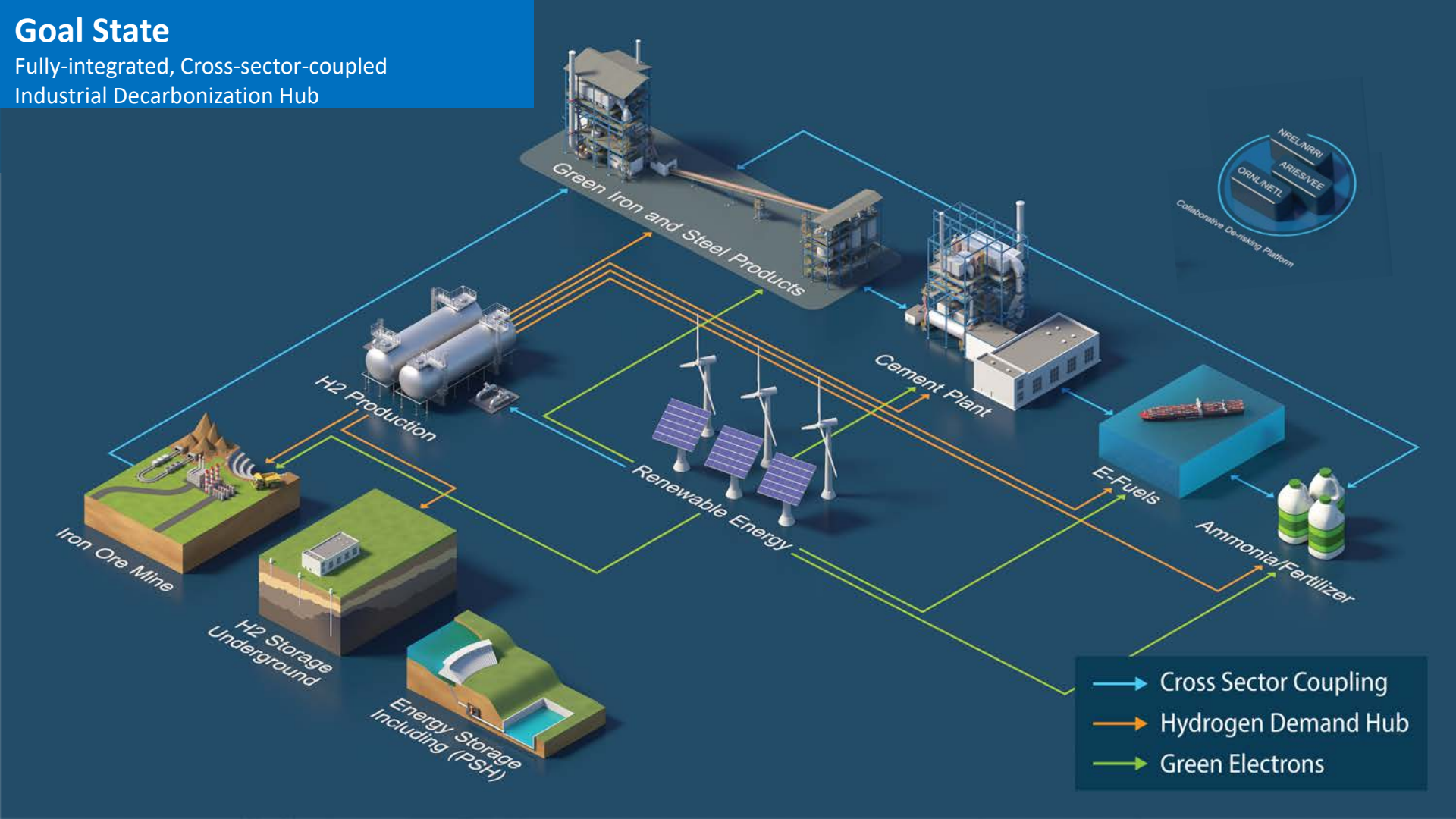
Research/De-risking Platform

1GW Green Iron/Steel Production (2032→)



Goal State

Fully-integrated, Cross-sector-coupled
Industrial Decarbonization Hub



Impacts & Challenges

Manufacturing Today

- ✓ Investment in next generation industry
  - New jobs, work force development, housing
- ✓ Community inclusion
  - Continual outreach, updates; Break traditional practices
- ✓ Broader portfolio of Minnesota iron products
  - Offtake markets; changing economy dynamics
- ✓ Cross-coupled industries
  - Inter-industry cooperation, incentives; Identify benefits
- ✓ Reduced CO2, carbon footprint
  - LCA verification; quantify national & global impact
- ✓ Enhanced global competitiveness
  - Markets shifting to “green-sourcing”
- ✓ Retain value/opportunity in Minnesota and region
  - Reinvest in economy, communities, environment
- ✓ Minnesota as national decarbonization model
  - Build productive partnerships to help accelerate national priorities

Takeaways

No Jitter

- ✓ **I2D** = once in a lifetime, finite window of opportunity to fundamentally change our global carbon footprint and reframe the Minnesota economy
- ✓ Embrace the conversation **today**
- ✓ Engage in discussions & planning **tomorrow**
- ✓ **Own the opportunity**

What can we accelerate by working together?

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

COMMUNITIES LEAP
U.S. DEPARTMENT OF ENERGY

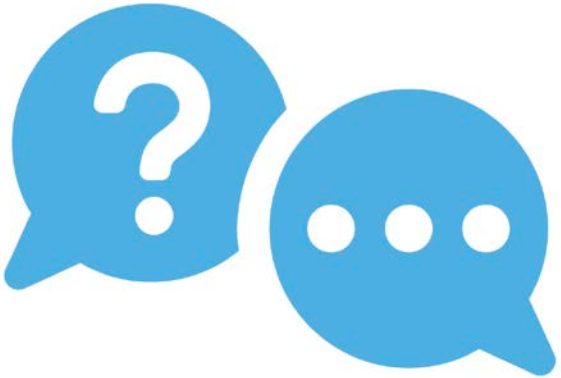
Natural Resources Research Institute
UNIVERSITY OF MINNESOTA DULUTH
Driven to Discover®

Thank You

SESSION 1

Hard-to-Decarbonize Industries

Day 1: 10:15 a.m.–1:15 p.m.



Moderated Q&A

Hard-to-Decarbonize Industries

Day 1: 10:15 a.m.–1:15 p.m.

Collaborative Activity

Quad Chart Exercise

Scenario: The DOE plans to invest billions of dollars to establish *Net-Zero Industry Hubs.*

Exercise: Outline and then prioritize (weight) the factors that should influence the selection process. Keep in mind that this needs to be just, sustainable, and integrated.

1. **Who** (stakeholders) do you want **commitments** from?	2. What **critical elements** will you look **for** in a **successful** proposal?
3. What **challenges** do you expect **mitigation plans** for?	4. What **commitments** are **you willing to make** to support decarbonization

Thank you!

We invite you to the virtual JAM24 synthesis meeting on April 8, 2024, 11:30 a.m.–1 p.m. MT.

Join us via Microsoft Teams by visiting
bit.ly/JAM24-synthesis

NREL/PR-6A50-89104

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