

“A” IS FOR AMMONIA: Why and how fertilizer may power the planet

Nicholas E. Thornburg, Ph.D.

CSM Global Studies Guest Lecture

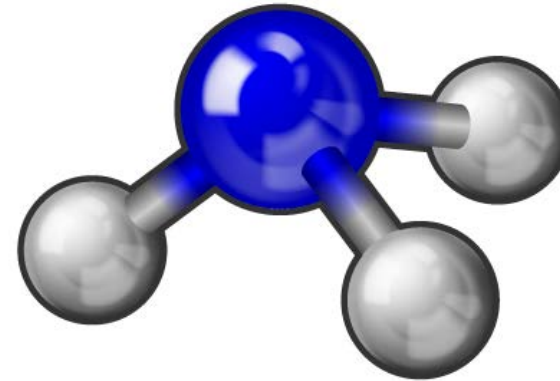
September 30, 2024

Senior Chemical Reaction Engineer

Energy Conversion and Storage Systems Center

Mechanical & Thermal Engineering Sciences Directorate

National Renewable Energy Laboratory (NREL), Golden, CO





NREL at-a-Glance



4,100

Workforce, including

205 postdoctoral researchers
179 graduate students
94 undergraduate students



World-class

facilities, renowned
technology experts

More than
1000

Partnerships

with industry,
academia, and
government



Campus

operates as a
living laboratory

Introduction

- B.S. Chemical Engineering, Washington University in St. Louis, 2012
- Ph.D. Chemical Engineering, Northwestern University, 2017; *doctoral research sponsored by Dow Chemical*
 - Dissertation Title: “Understanding Silica-Supported Group 4 and 5 Metal Oxide Catalysts for Selective Oxidations with Hydrogen Peroxide and for Epoxide Activation”
- Former graduate intern at 3M, Corporate Research Materials Laboratory, 2015; *adhesive formulation R&D*
- ***Senior Reaction Engineer (and other roles) at the National Renewable Energy Laboratory, 2017–present***
- Adjunct Professor of Chemical Engineering, Colorado School of Mines, January 2024–present



Overview of what I do for a living

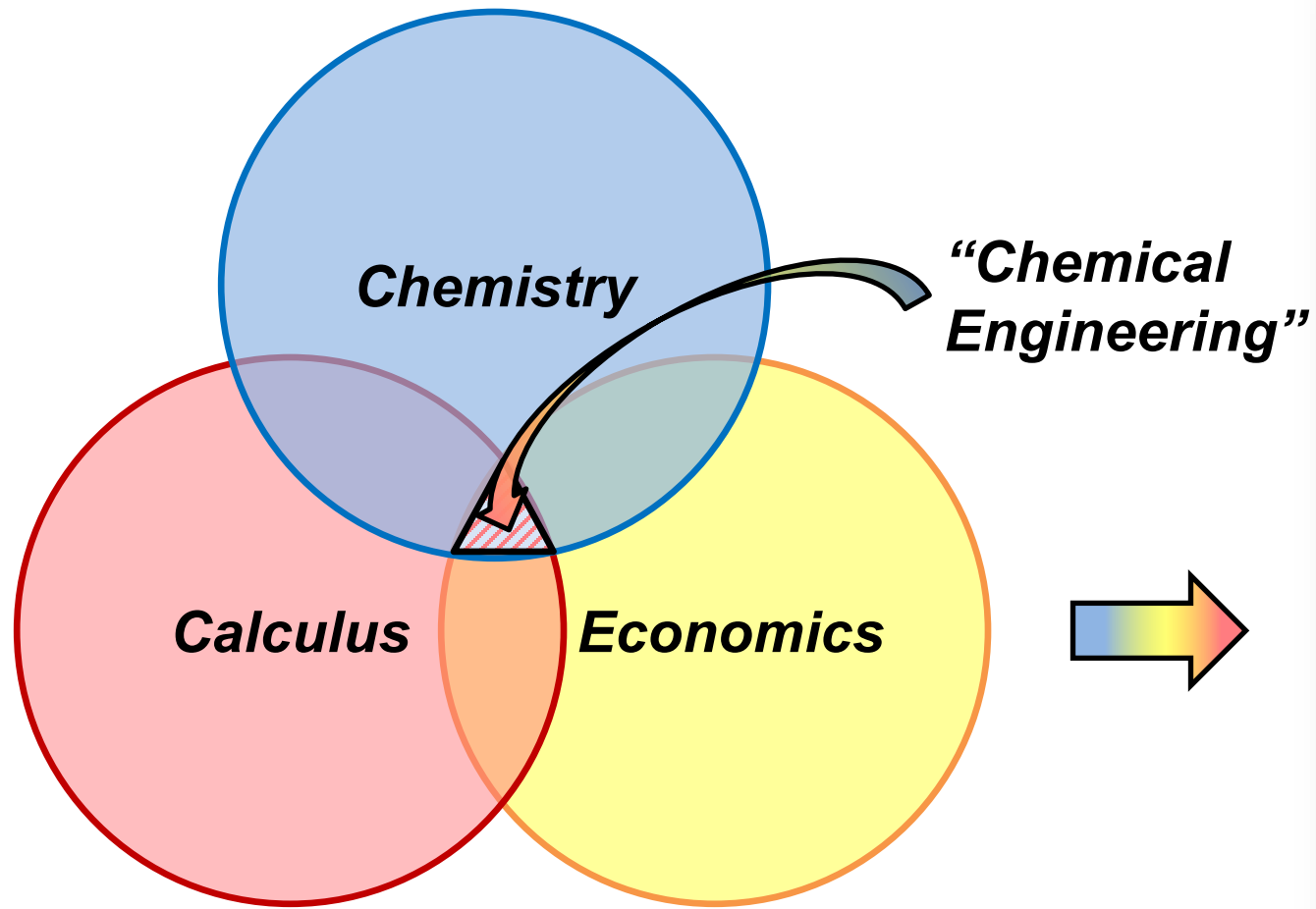
I investigate **catalysts & reactors** for the **sustainable** production of **chemicals & fuels**.

“I make the stuff that makes the stuff that makes the stuff, **better**.”

Chemical engineering – chemistry... at the largest possible scale!

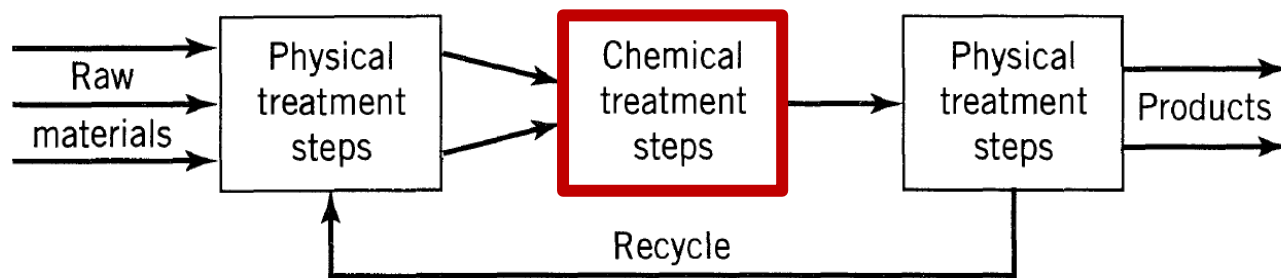


Chemical engineering – chemistry... at the largest possible scale!



Chemical engineering – chemistry... at the largest possible scale!

- **Industrial chemicals** are EVERYWHERE in our homes, cars and everyday lives
 - performance plastics & fabrics
 - foams, coatings, paints & adhesives
 - cosmetics, hygiene & cleaning products
 - pharmaceutical drugs
- **nitrogen fertilizer** (*today's lecture*)



#TBT: the dawn of the 20th Century

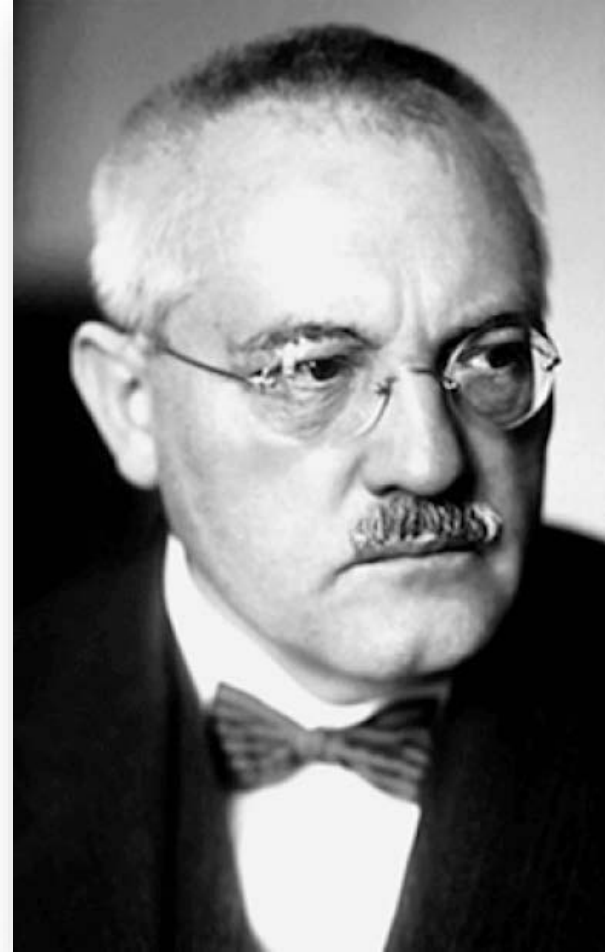


A tale of two scientists

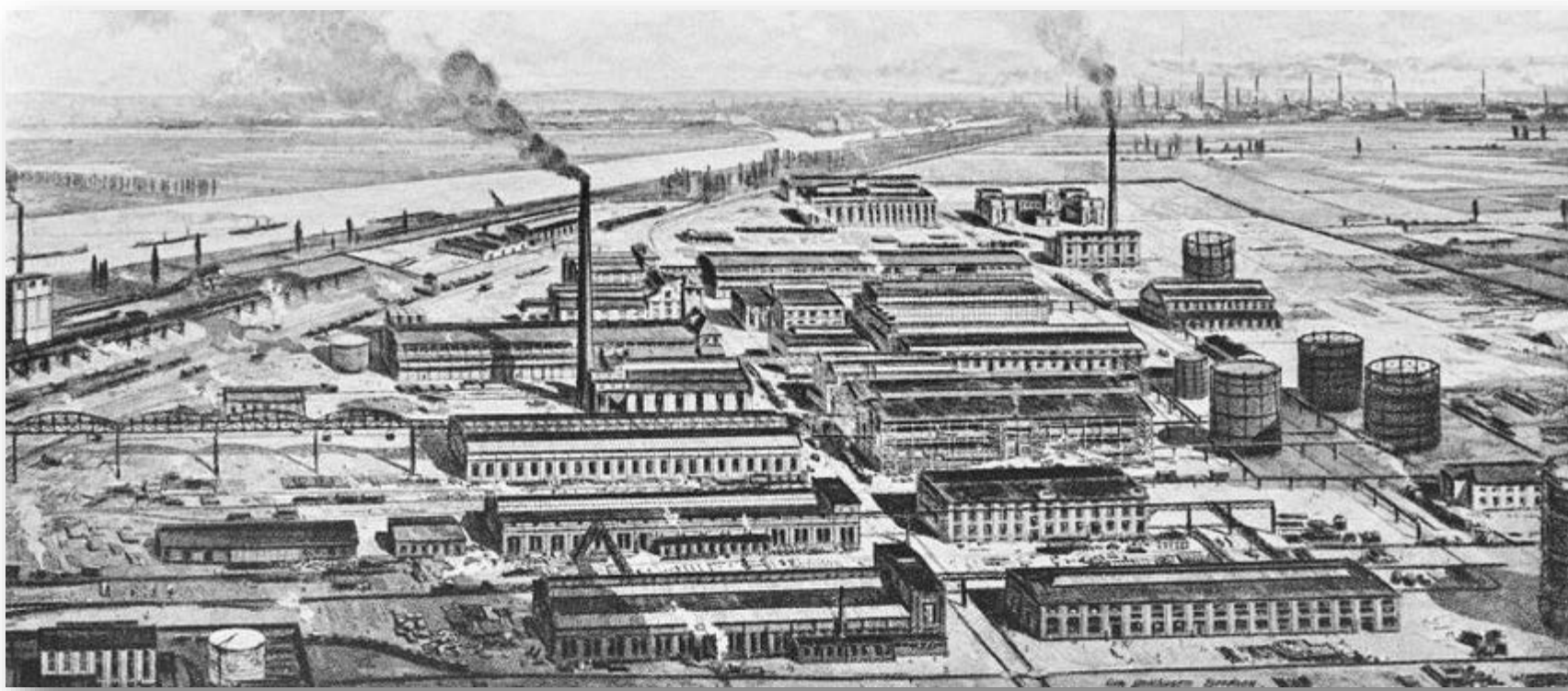
Fritz Haber



Carl Bosch

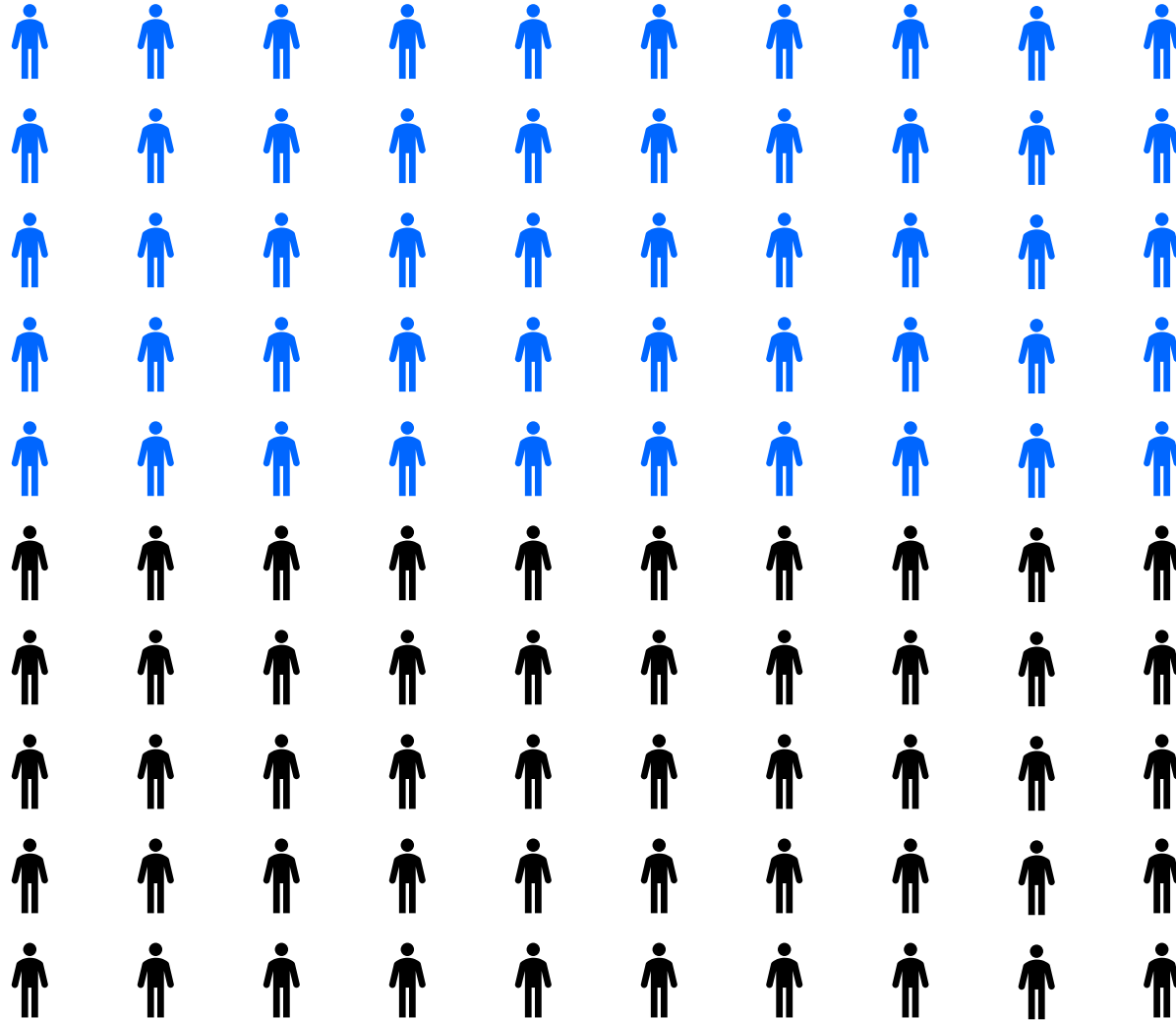


Life—and death—from ammonia's very discovery

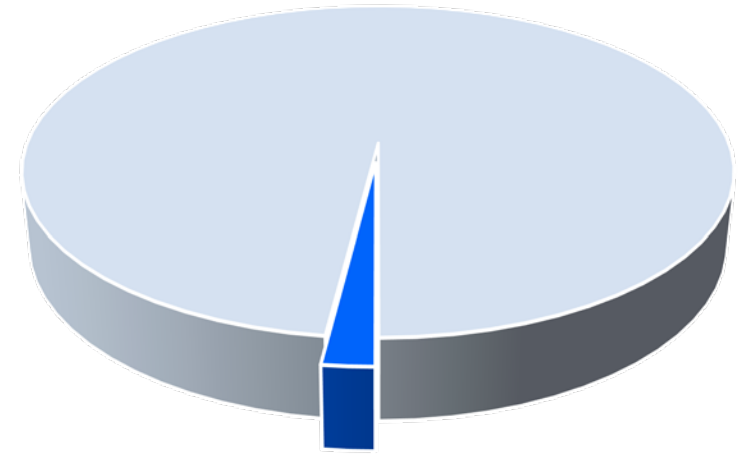
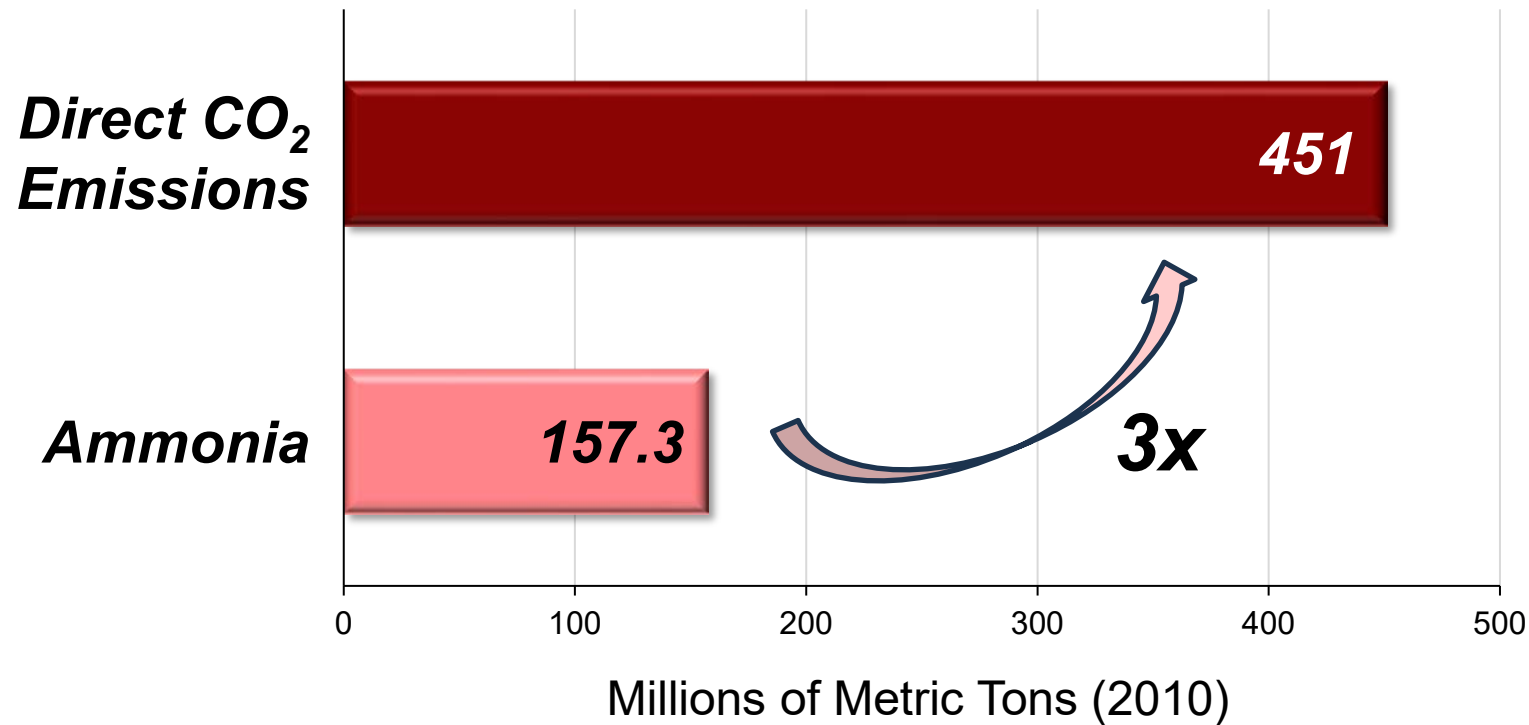


BASF ammonia plant in Oppau (Ludwigshafen, Germany, 1913)





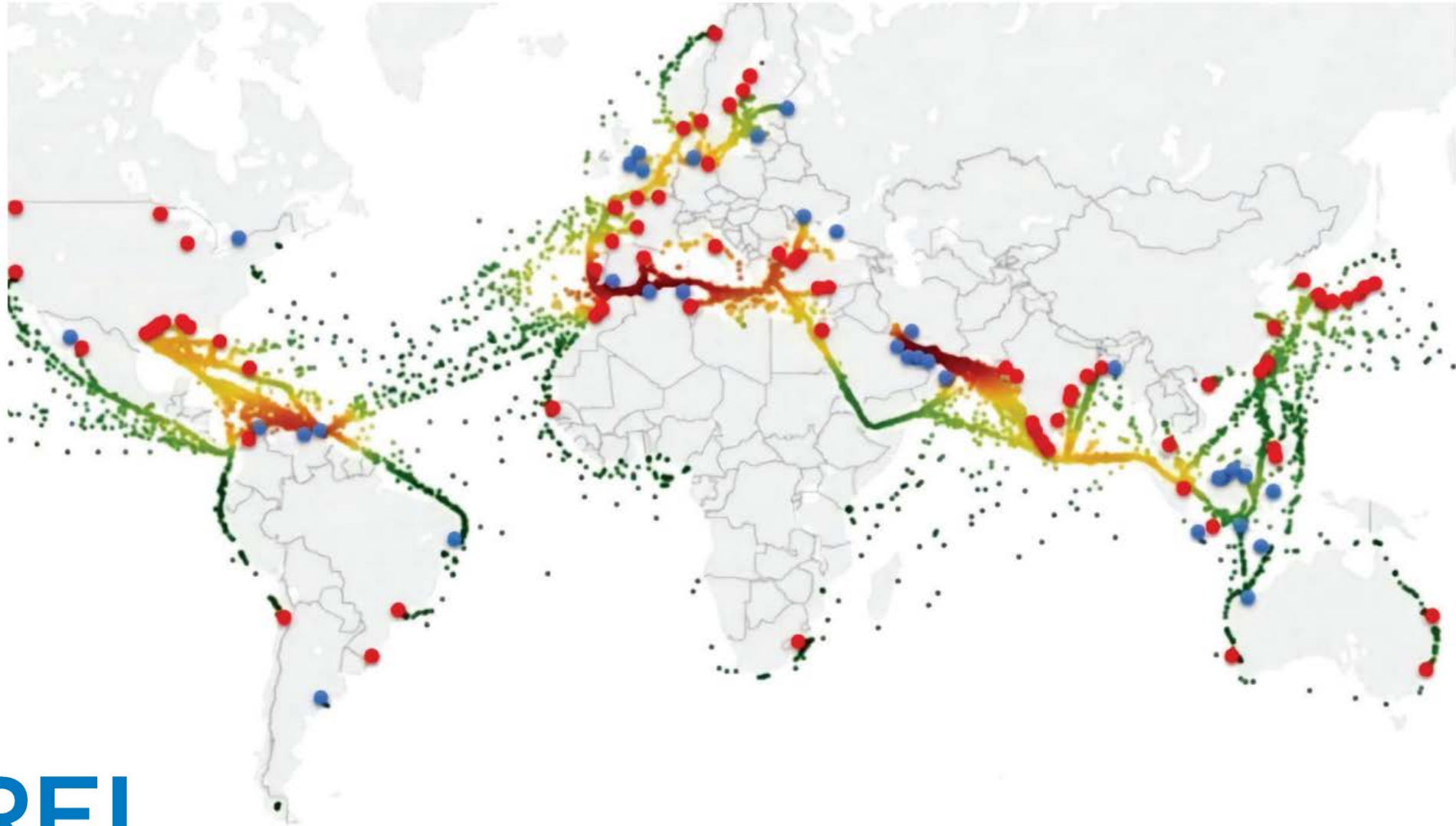
BUT... feeding the planet hurts the planet



NH₃ consumes
1–2%
of the world's
energy supply

A crisis of food equity

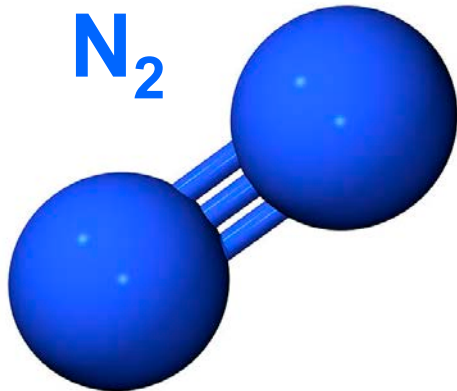
- Ammonia loading facilities
- Ammonia unloading port facilities



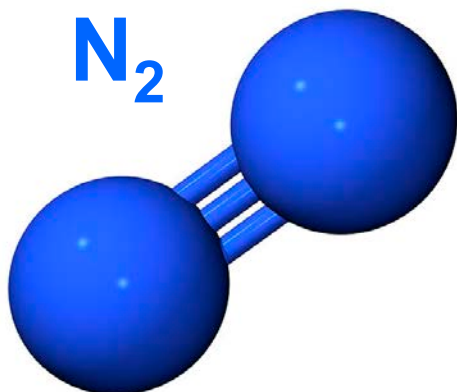
Rethinking the paradigm



An uphill battle



Nitrogen's **triple bond** is extremely stable—*requiring lots of energy to break it.*

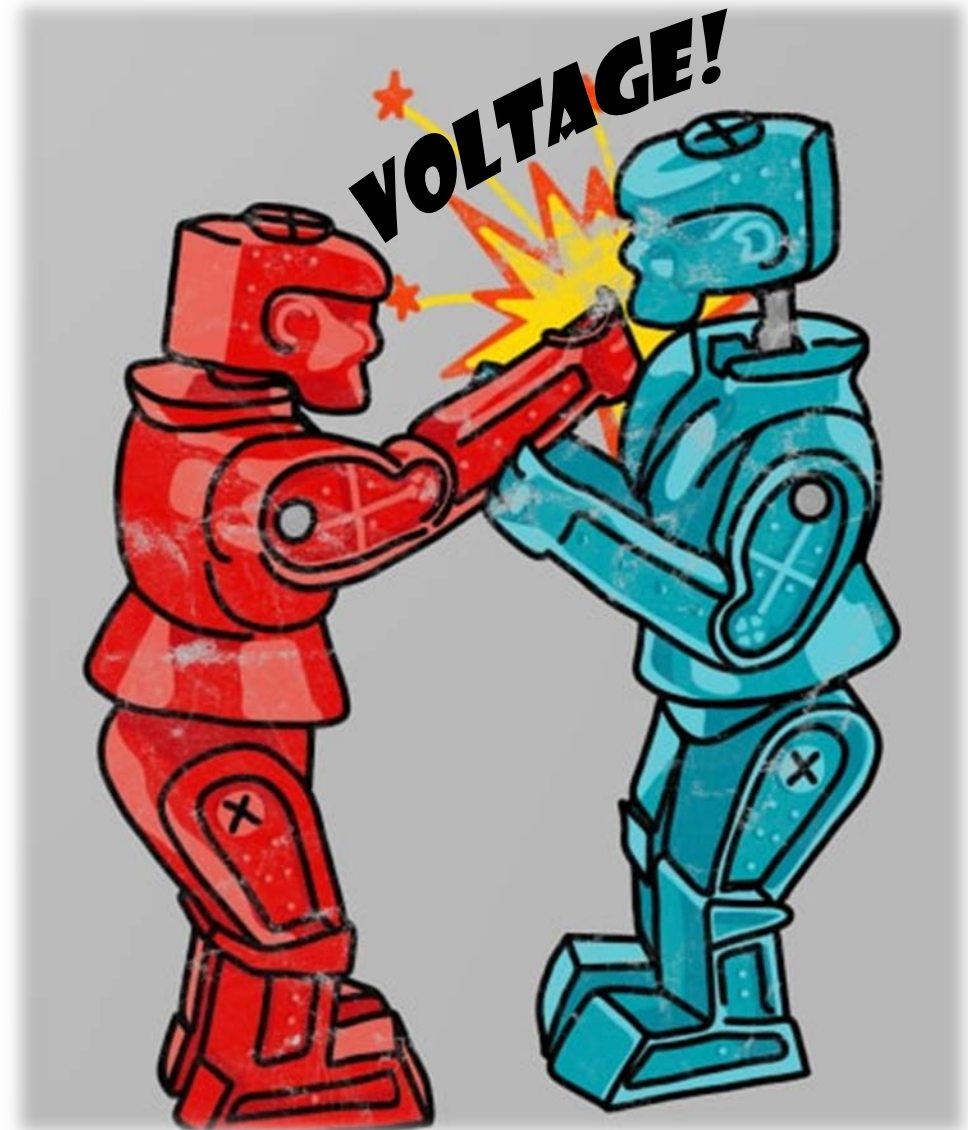


Nitrogen's **triple bond** is extremely stable—*requiring lots of energy to break it.*

The First Life Lesson of Thermodynamics

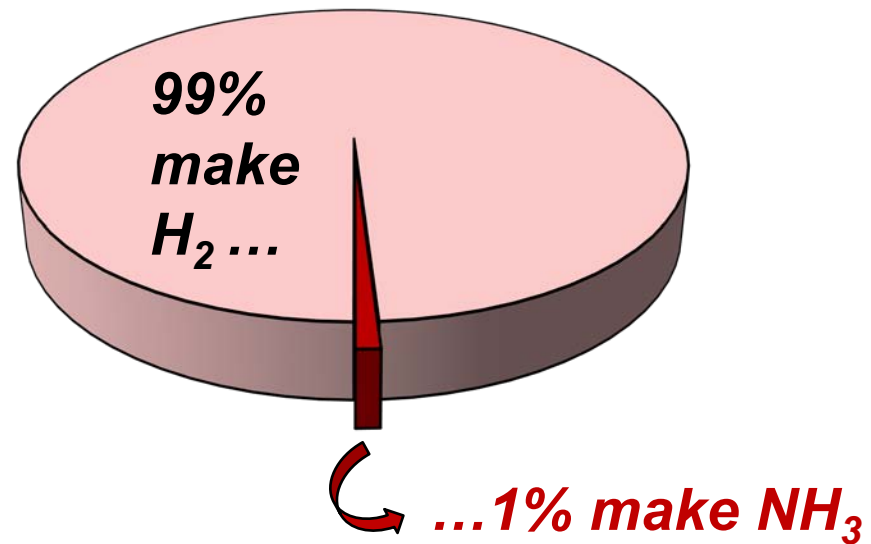
You break it, you buy it.

Electrochemistry helps tip the scales in ammonia's favor and allows us to utilize renewable inputs.



The Second Life Lesson of Thermodynamics

Electrons are a lot like kids.



Modularization unlocks the future of renewable NH₃ and food equity

Creates fertilizer when and where we need it...



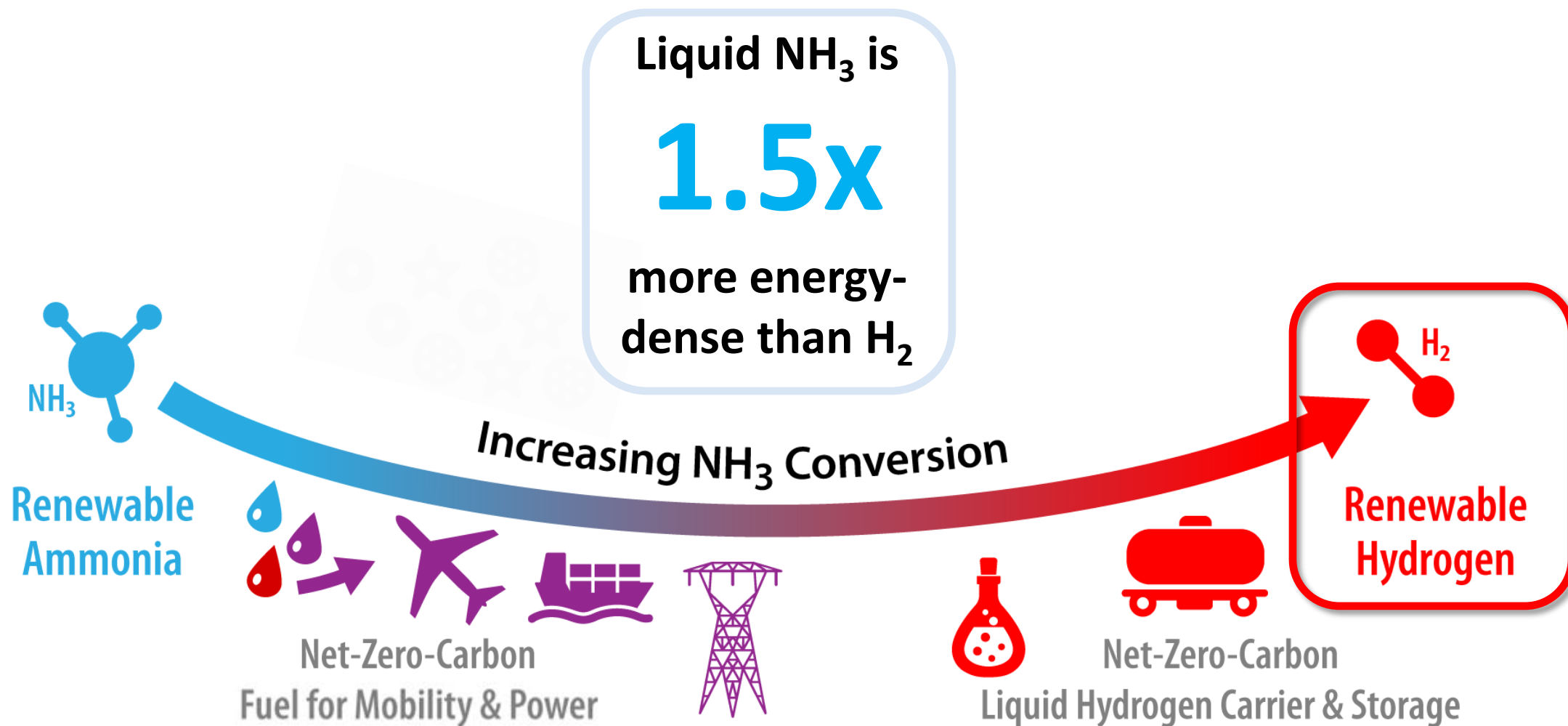
Modularization unlocks the future of renewable NH₃ and food equity

Creates fertilizer when and where we need it...

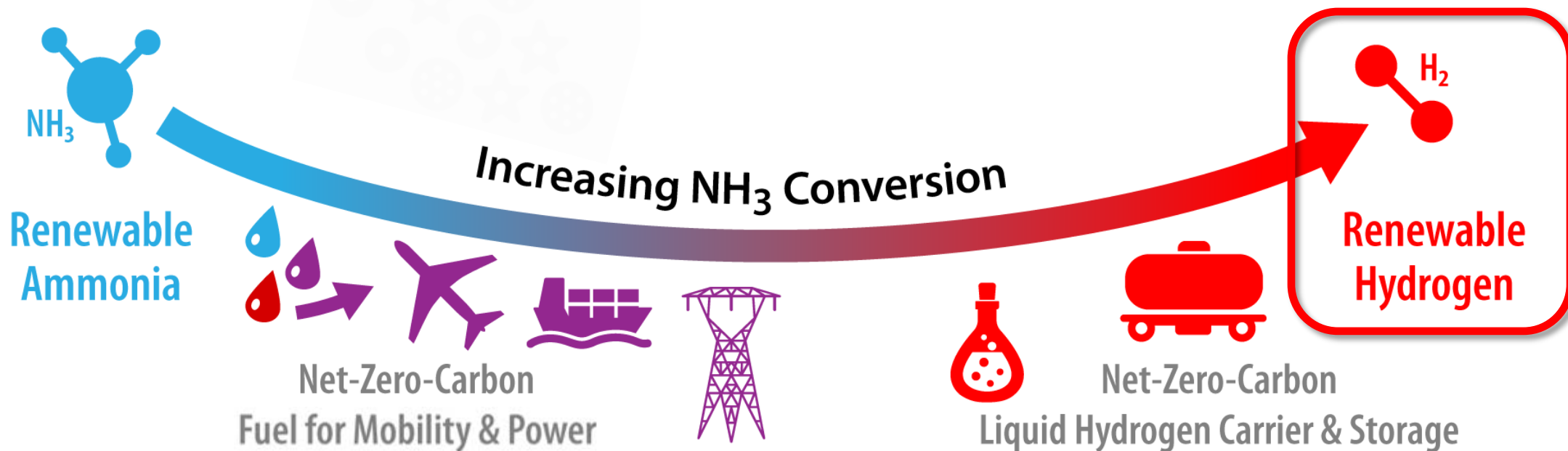


...only needs air, water and renewable electricity

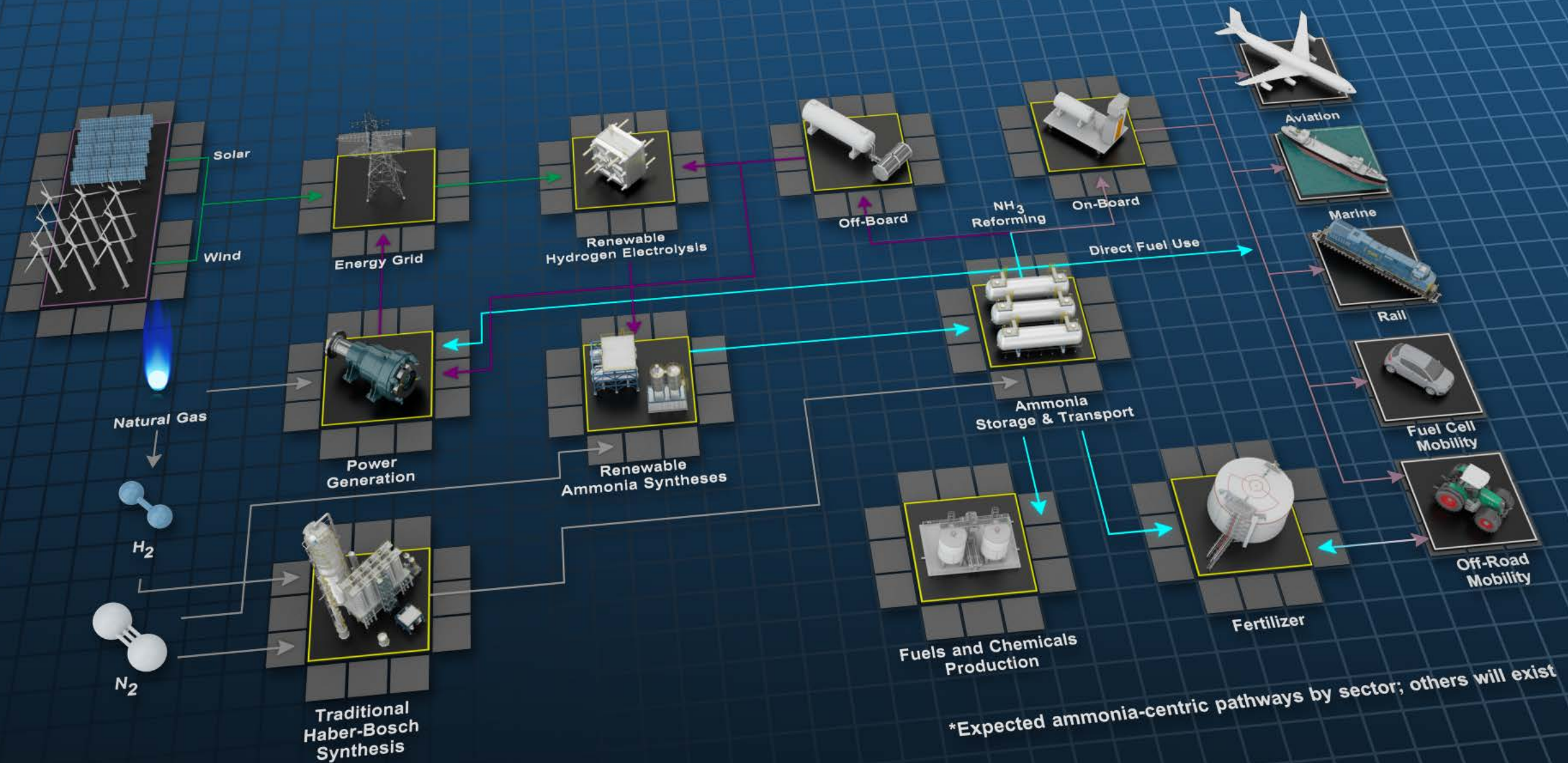
Reversing Haber-Bosch



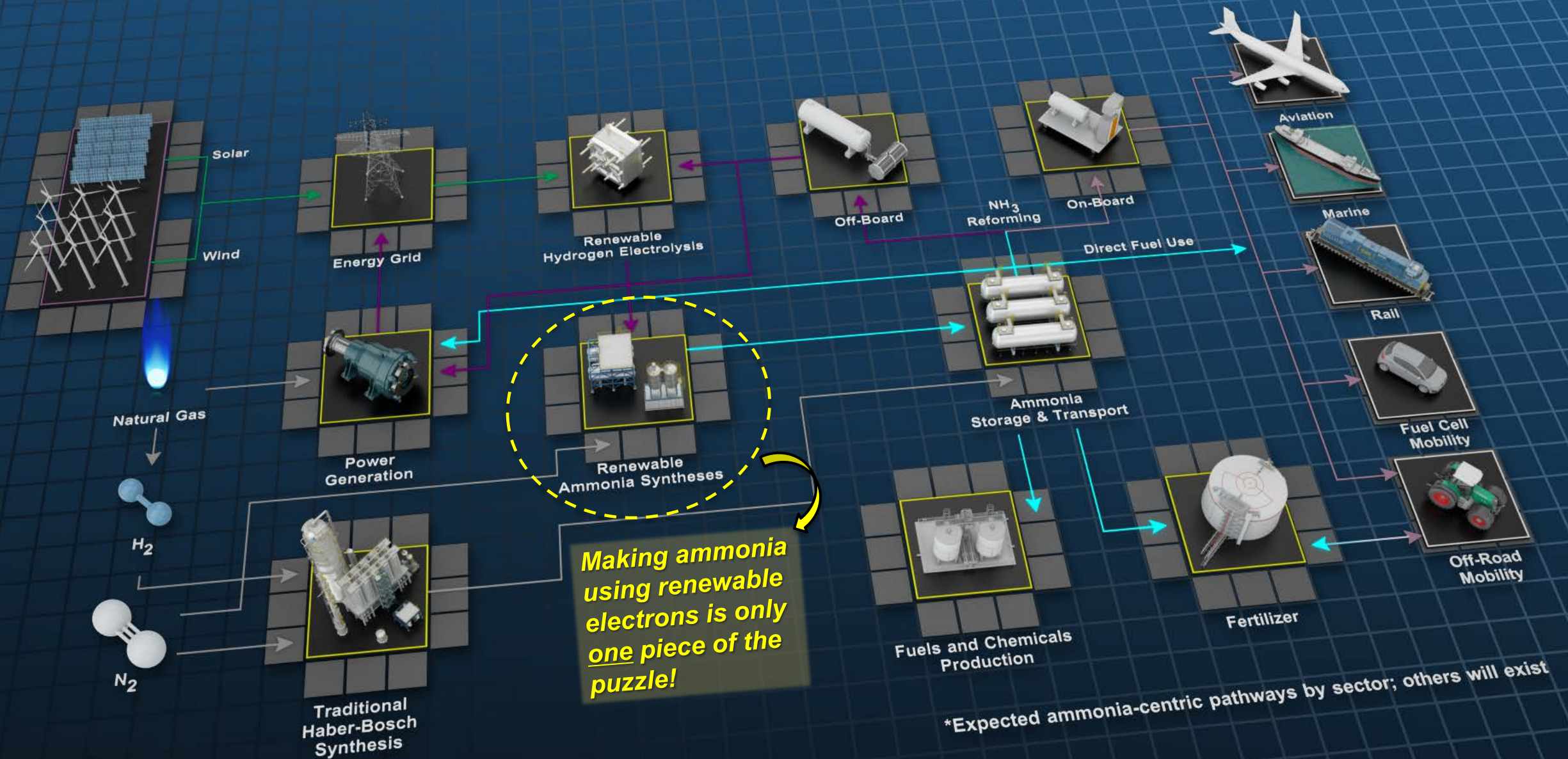
The Third Life Lesson of Thermodynamics
Sometimes, things work out the way you want.



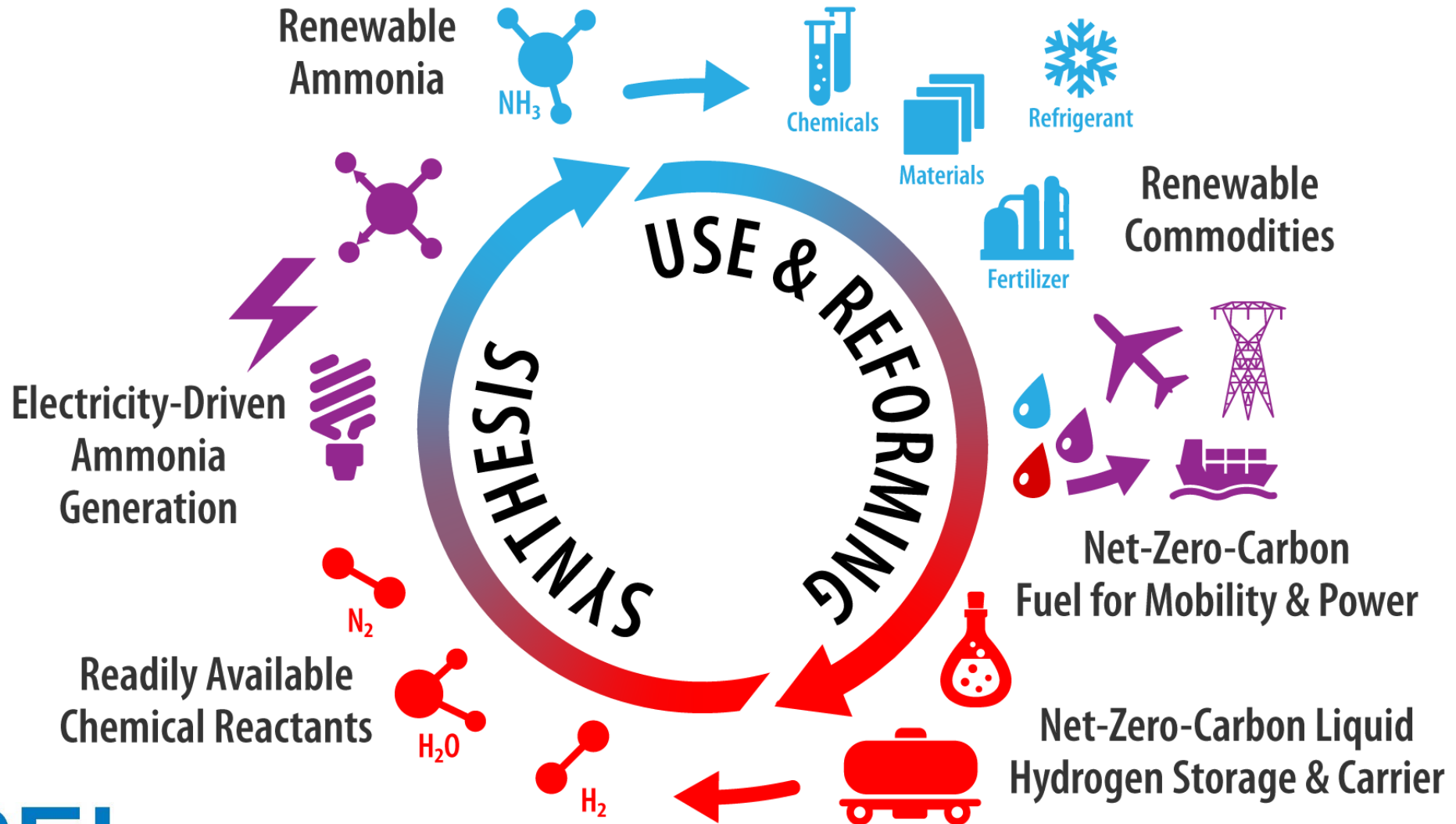
NREL is helping build the future ammonia energy economy



NREL is helping build the future ammonia energy economy



Circularity of nitrogen and hydrogen



A wide-angle photograph of a lush green agricultural field, likely corn, stretching to the horizon under a bright blue sky with scattered white clouds. The rows of crops are perfectly straight and recede into the distance, creating a strong sense of perspective.

What we plant now, we will harvest later.

NREL/PR-5700-91425

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Bioenergy Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.