

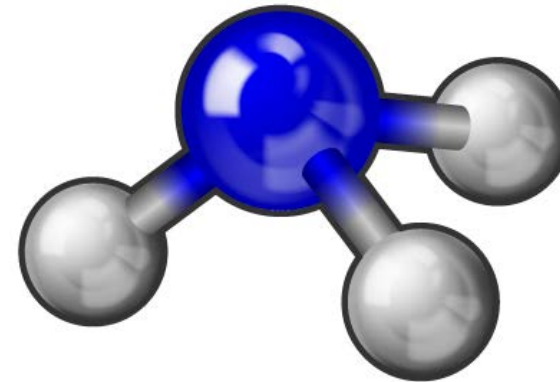
“A” IS FOR AMMONIA: Why and how fertilizer may power the planet

Nicholas E. Thornburg, Ph.D.

December 7, 2023

Switch

Senior Reaction Engineer
National Renewable Energy Laboratory
Golden, Colorado



#TBT: the dawn of the 20th Century

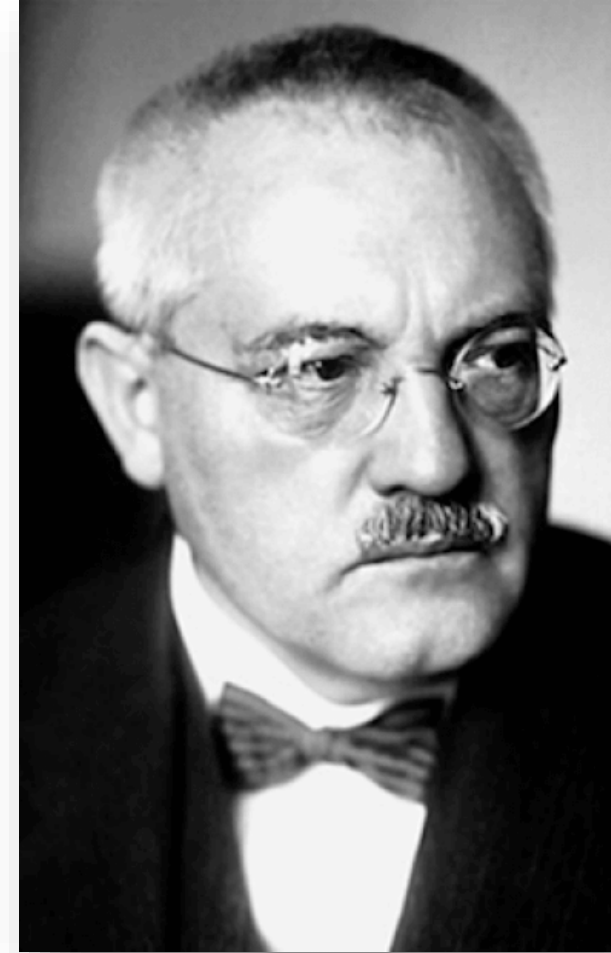


A tale of two scientists

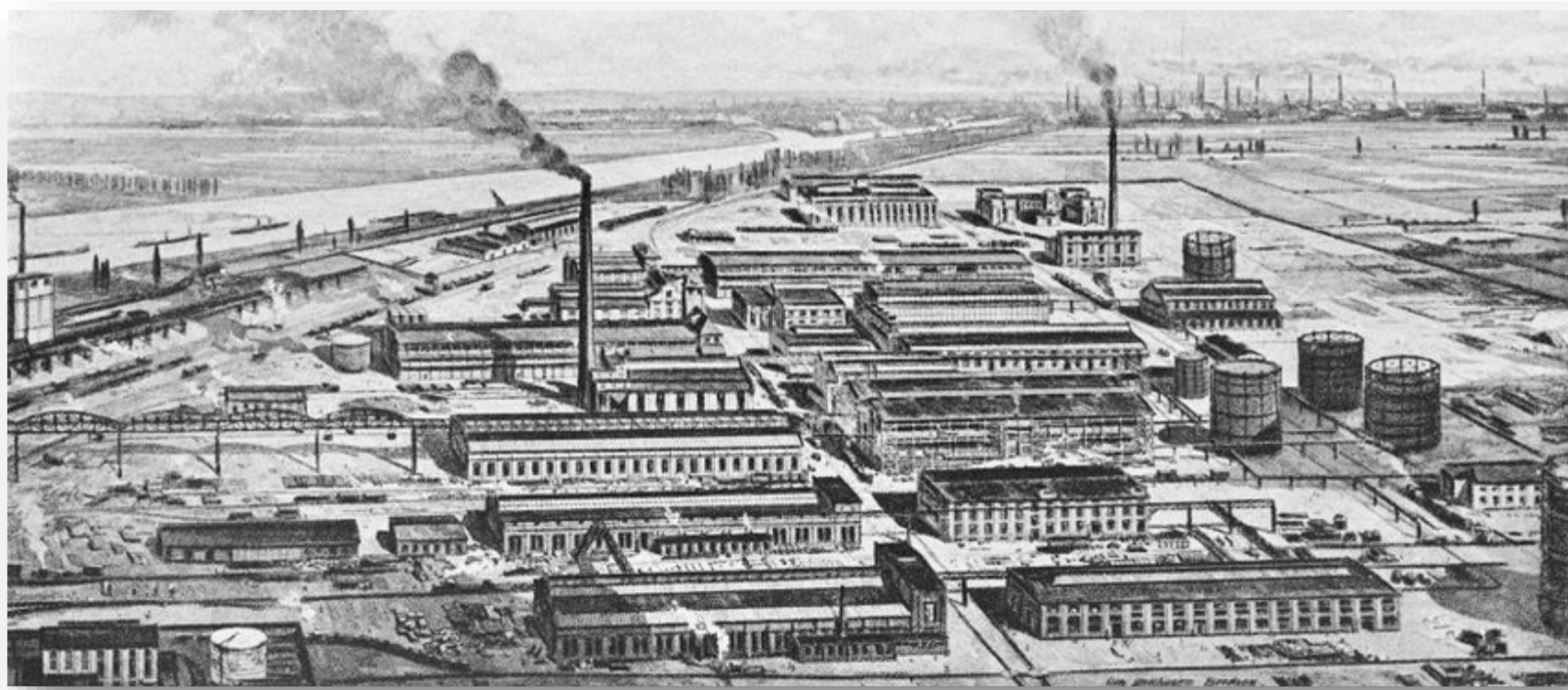
Fritz Haber



Carl Bosch

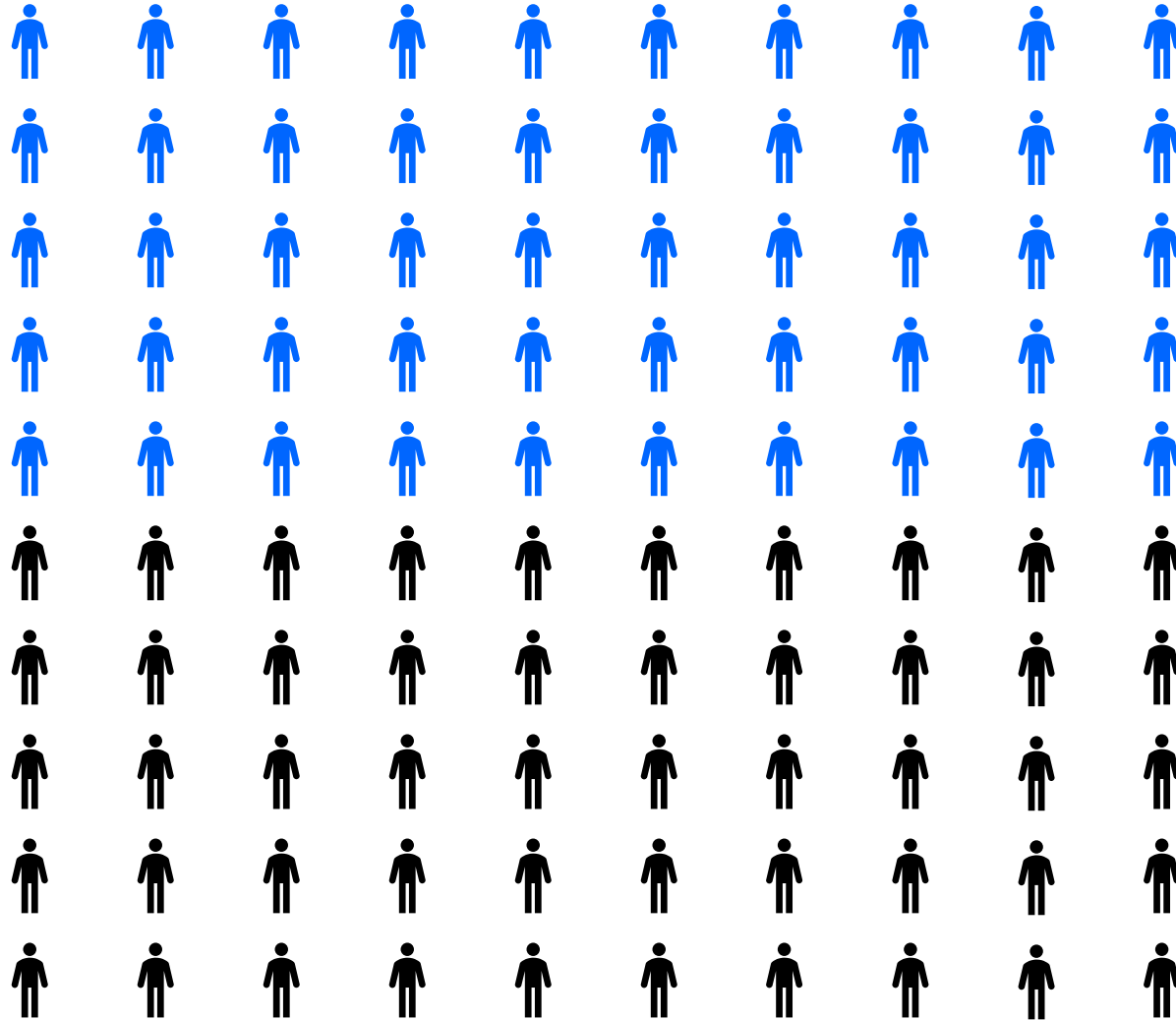


Life—and death—from ammonia's very discovery

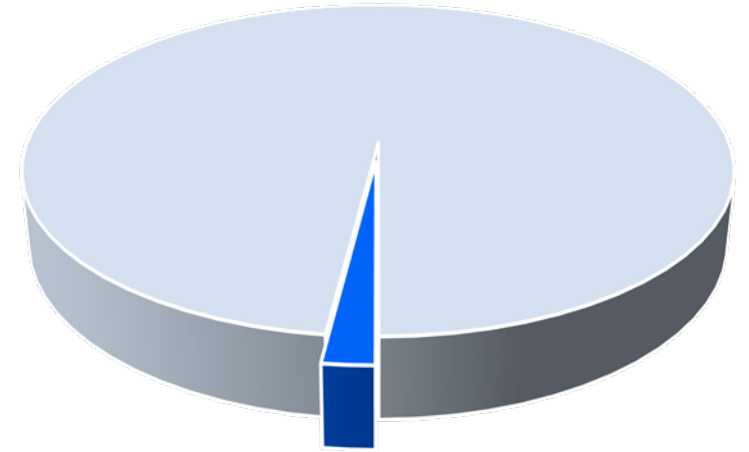
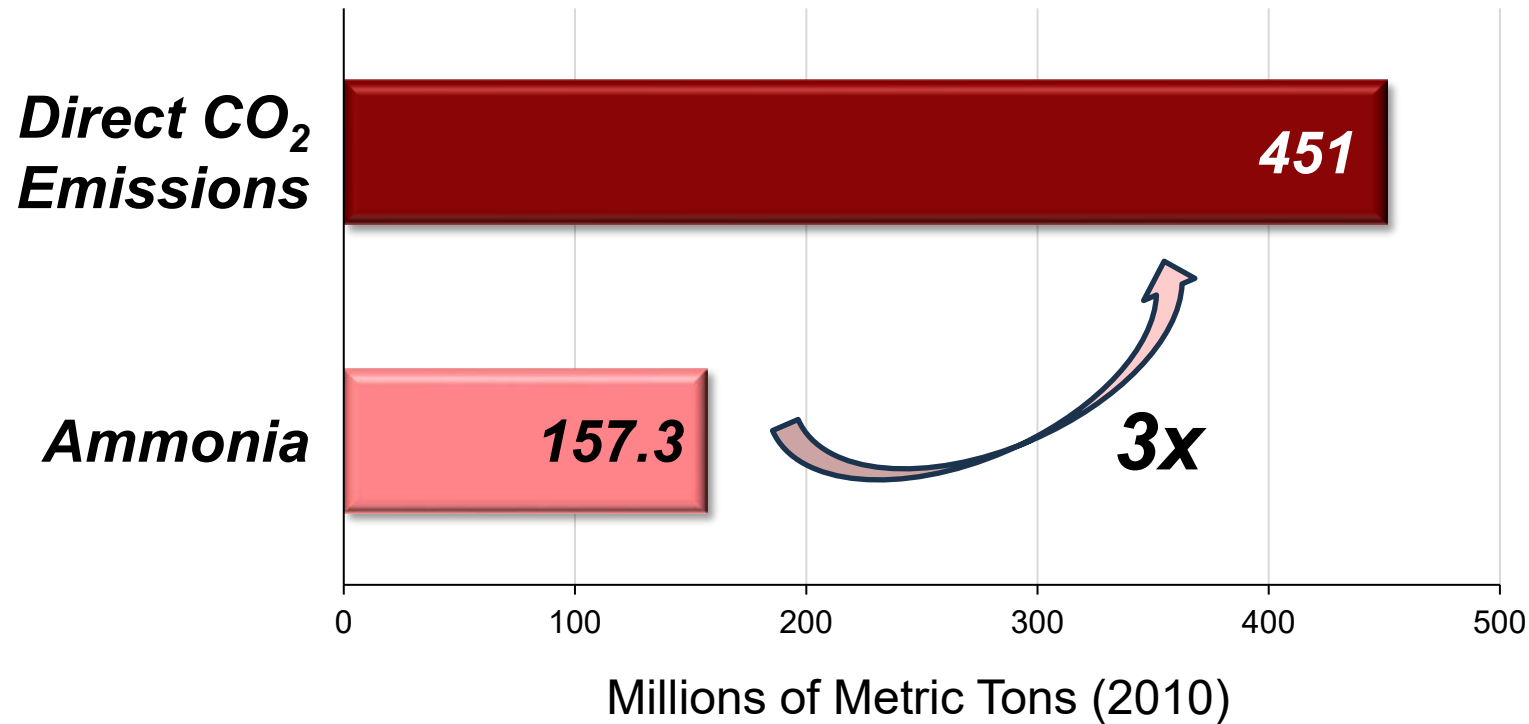


BASF ammonia plant in Oppau (Ludwigshafen, Germany, 1913)





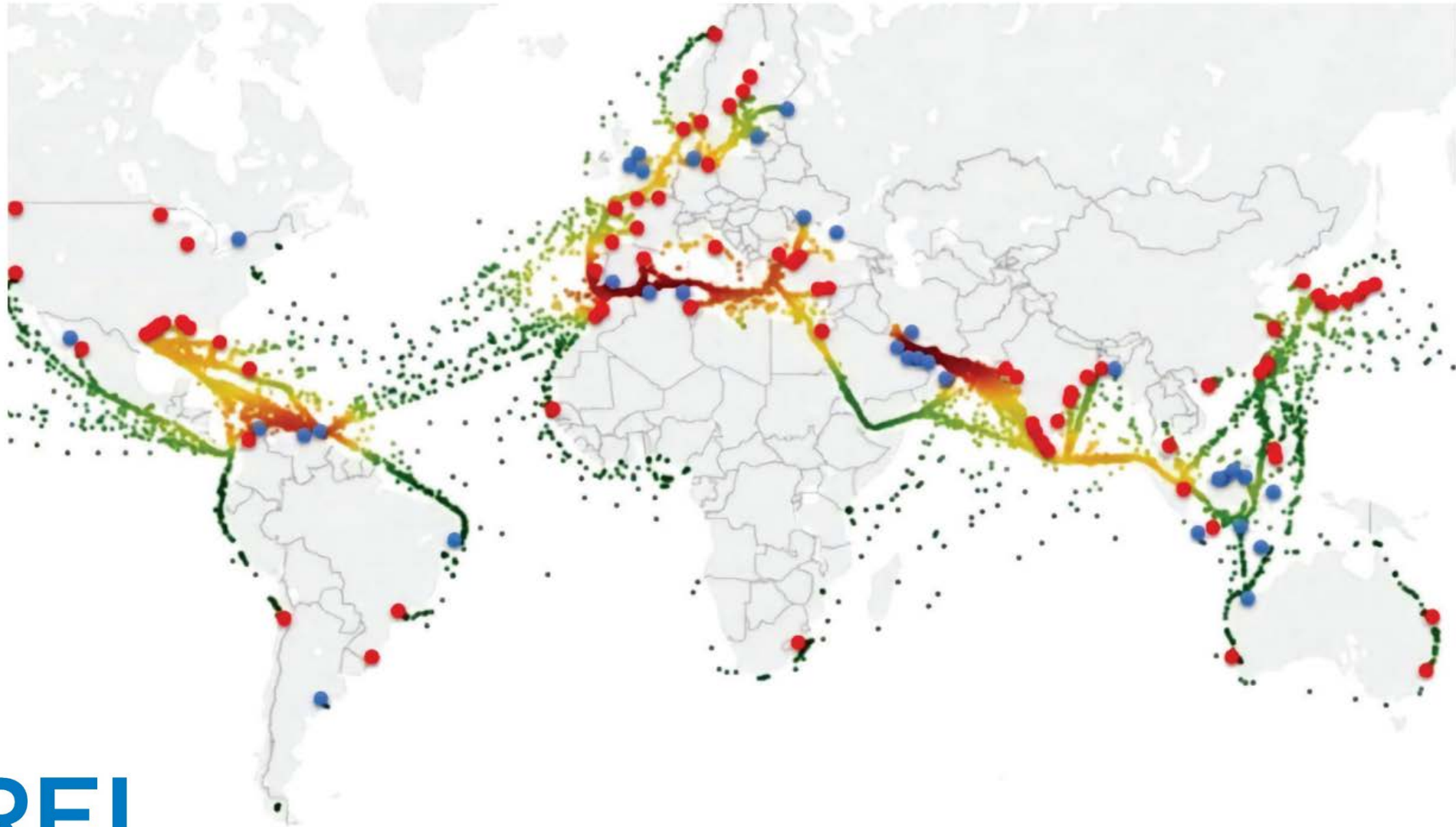
BUT... feeding the planet hurts the planet



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

A crisis of food equity

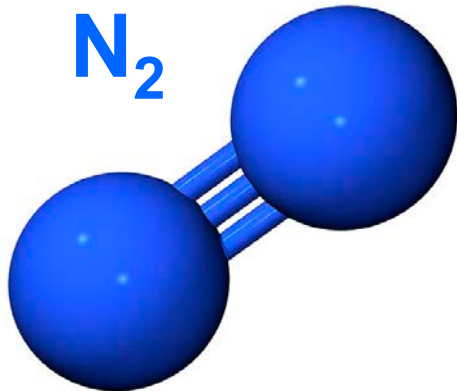
- Ammonia loading facilities
- Ammonia unloading port facilities



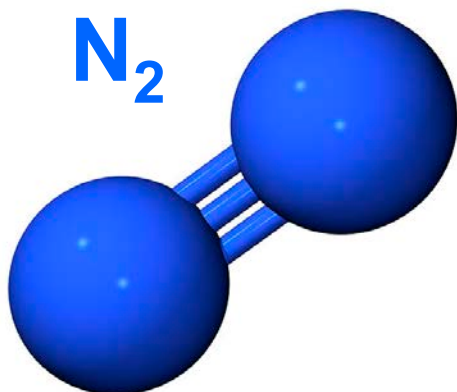
Rethinking the paradigm



An uphill battle



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

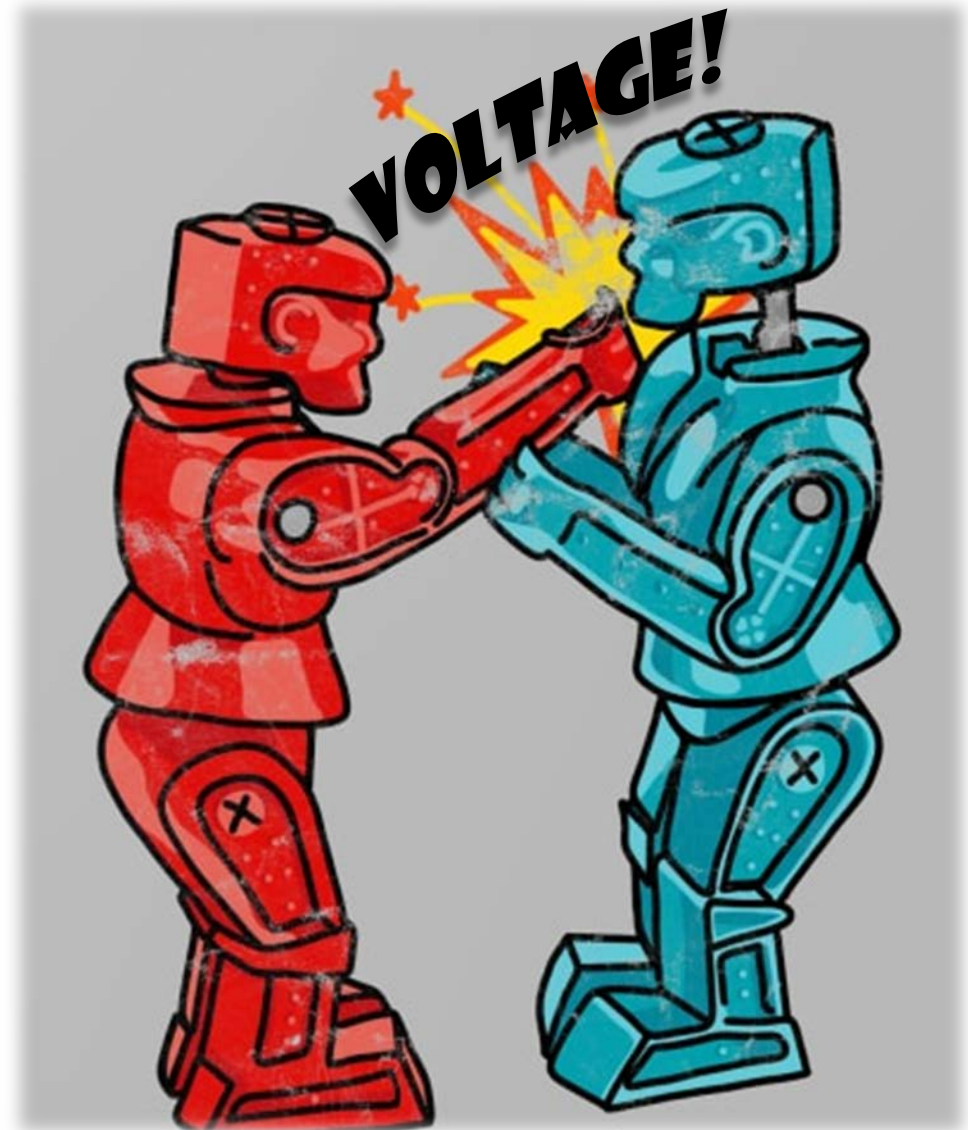


Nitrogen's **triple bond** is extremely stable—*requiring lots of energy to break it.*

The First Life Lesson of Thermodynamics

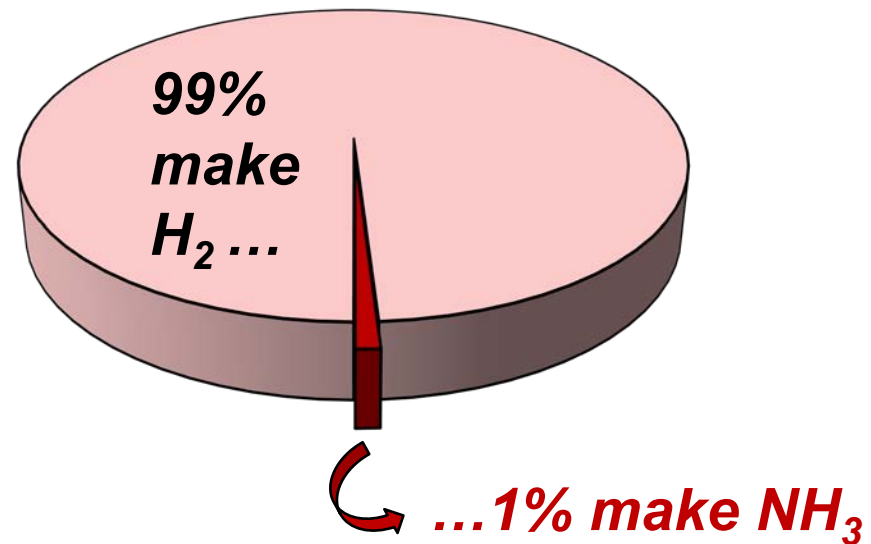
You break it, you buy it.

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...



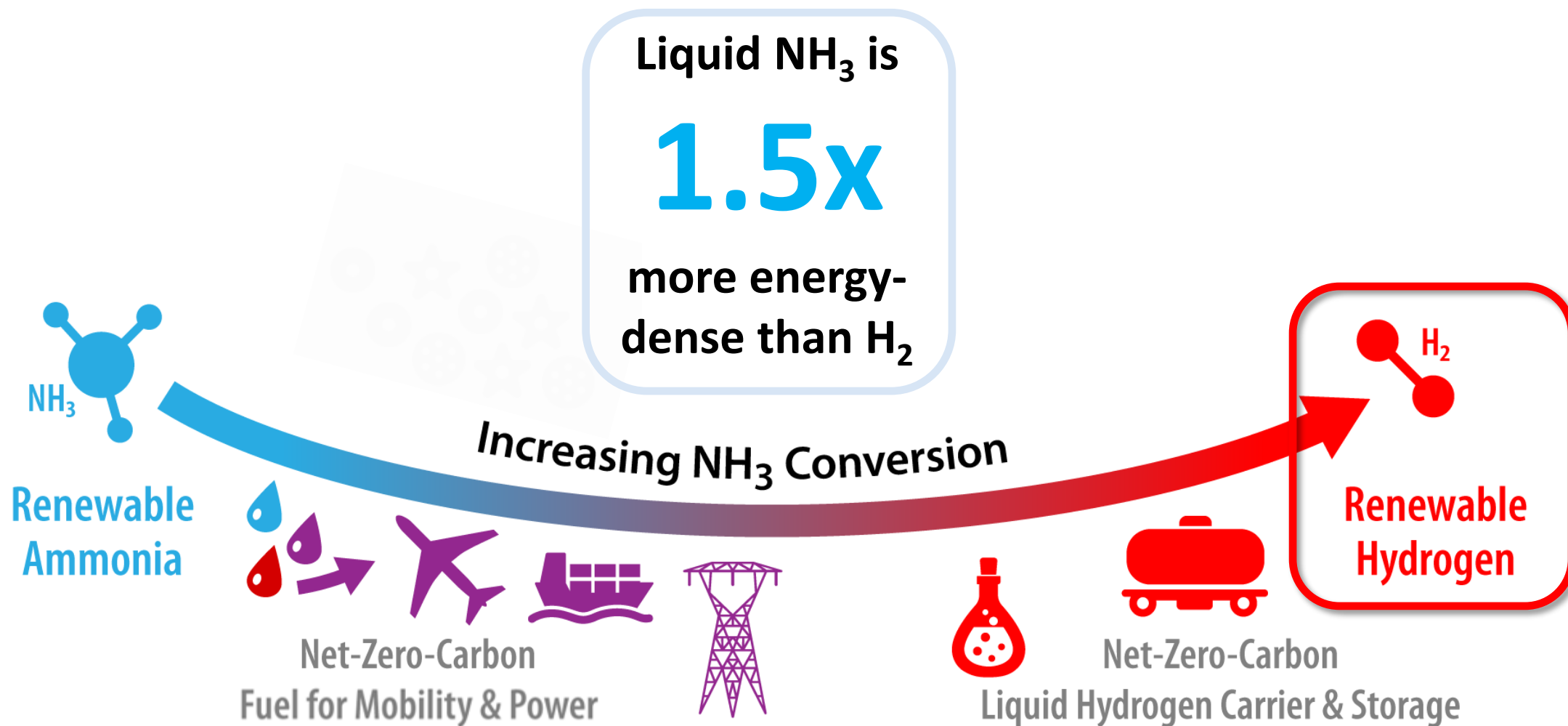
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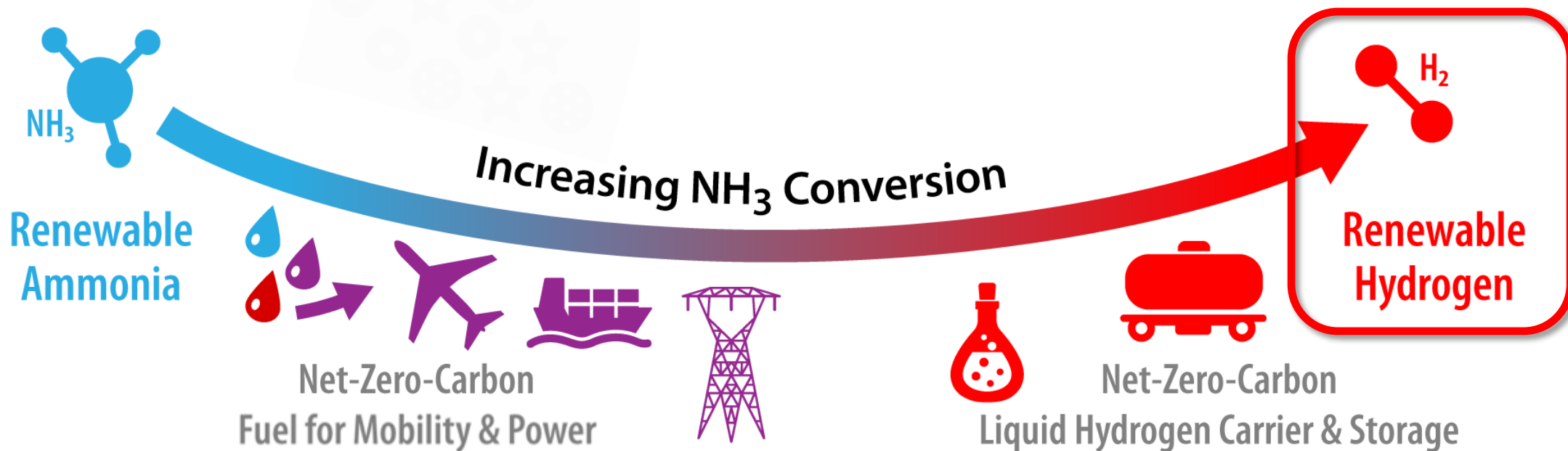


...only needs air, water and renewable electricity

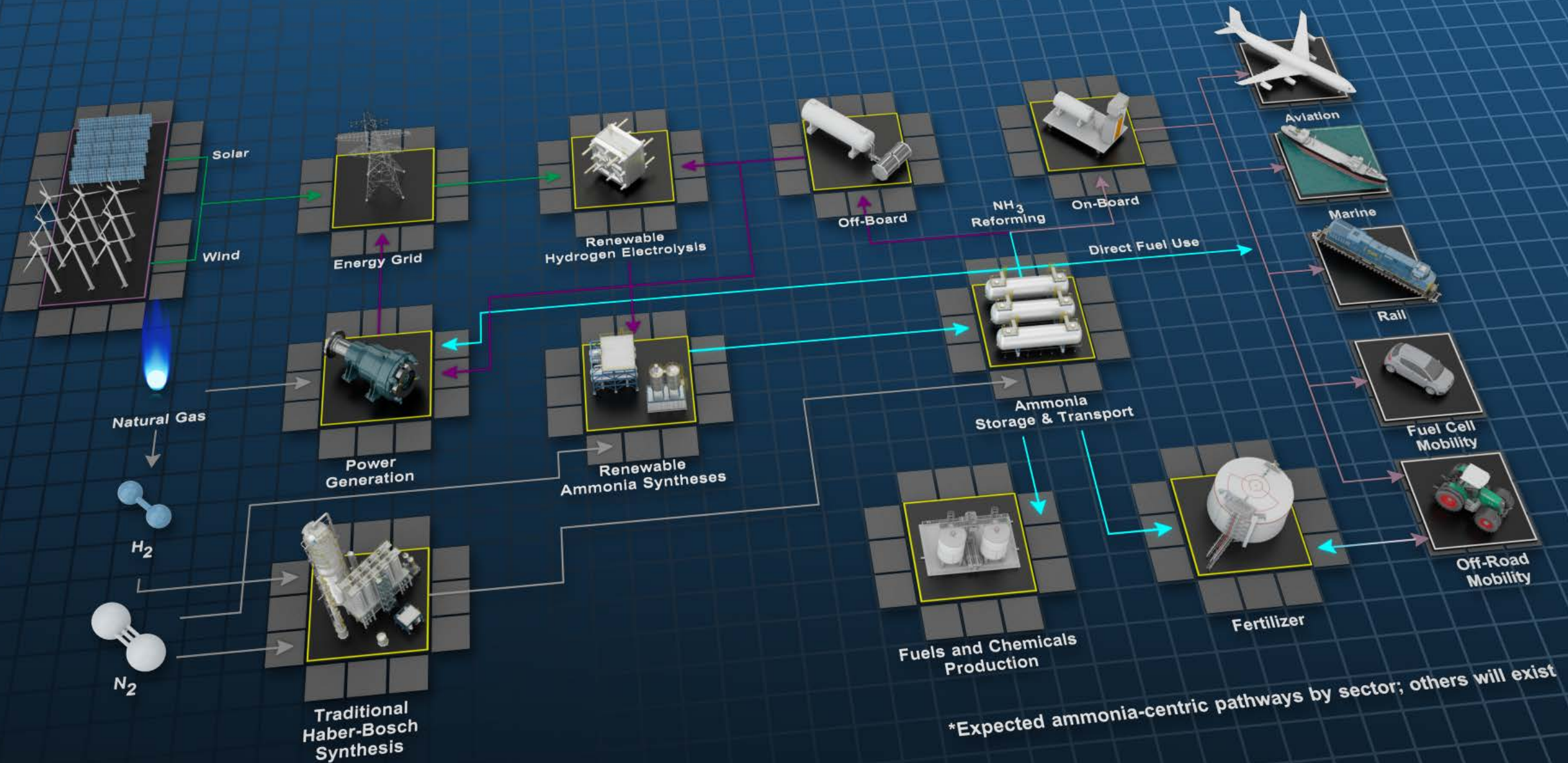
Reversing Haber-Bosch



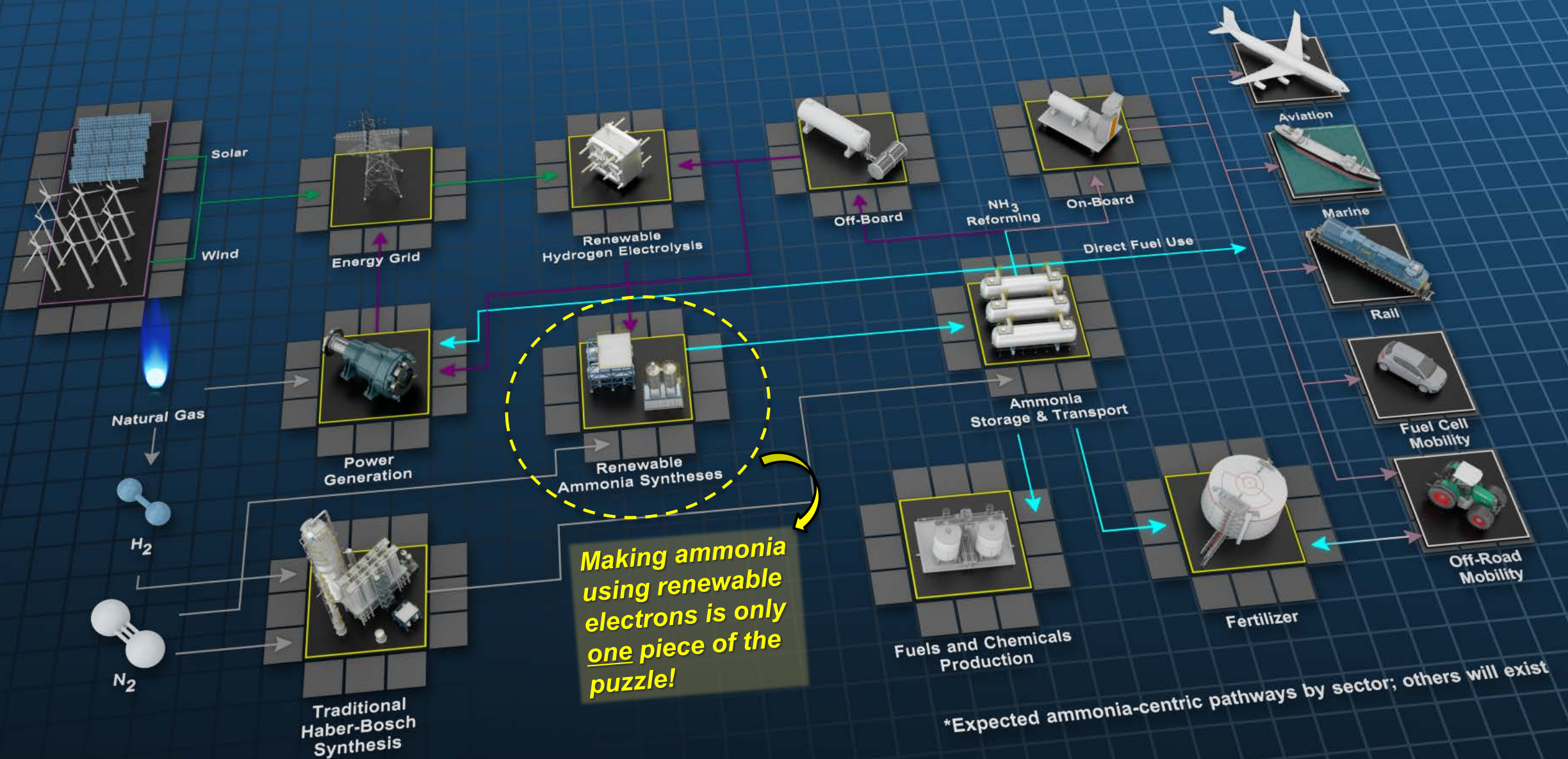
The Third Life Lesson of Thermodynamics
Sometimes, things work out the way you want.



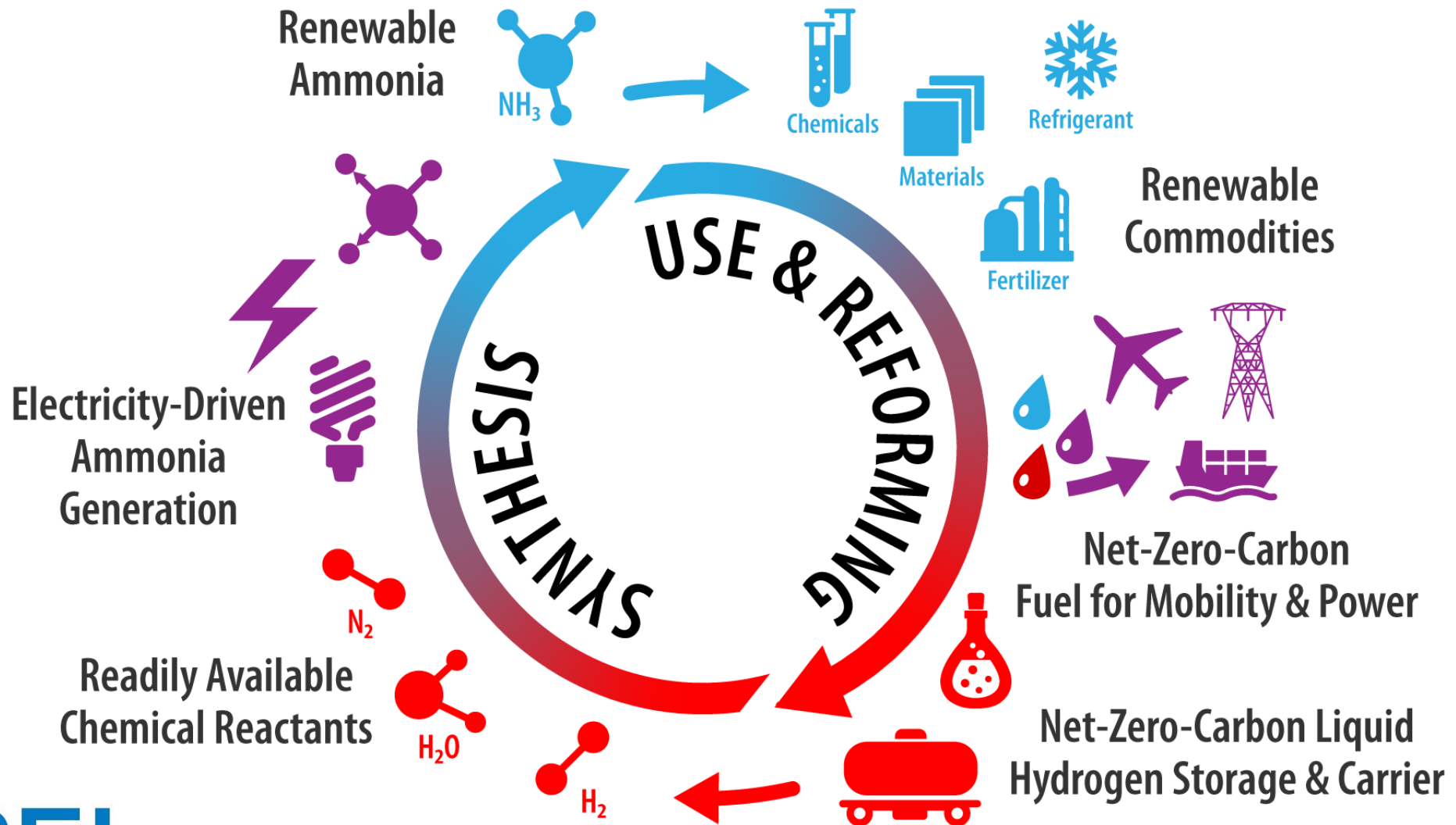
NREL is helping build the future ammonia energy economy



NREL is helping build the future ammonia energy economy



Circularity of nitrogen and hydrogen



What we plant now, we will harvest later.

