Model-based energy and emission analysis of ammonia production for improved process sustainability

Banafsheh Jabarivelisdeh[1], Enze Jin[1], Phillip Christopher[2], Eric Masanet[1,3]

[1] Bren school of Environmental Science and Management, University of California Santa Barbara, CA, USA

[2] Department of Chemical Engineering, University of California Santa Barbara, CA, USA

[3] Department of Mechanical Engineering, University of California Santa Barbara, CA, USA

IEA-ETSAP Workshop

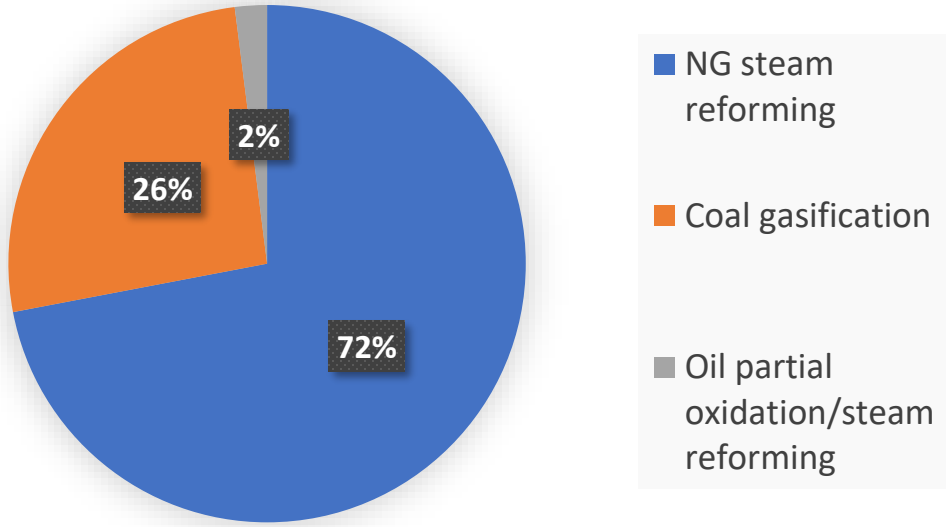
December 1st - 2022

industrial sustainability analysis lab

Ammonia production is unsustainable

Ammonia production is among the highest energy/emission intensive processes

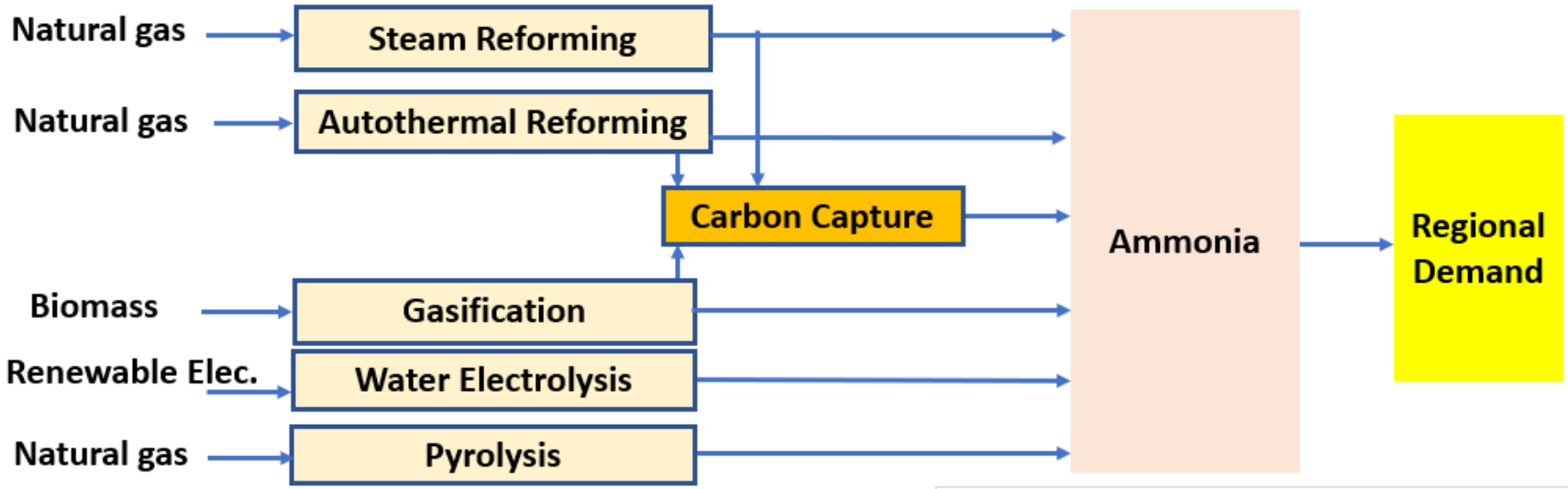
- One of the largest volume products in the chemical sector
- Current production relies on fossil fuels (Responsible for 50% and 44% of global chemical industry's demand for NG and coal, respectively)
- ~20% of chemical sector's energy usage in 2020
- ~35% of its CO_2 emissions in 2020
  Largest contributor to emissions within the chemical sector (~2.4 t-CO_2/t-NH_3)



Global production pathways (2020)

Promoting the sustainability of ammonia production is required for making it compatible with climate change mitigation goals

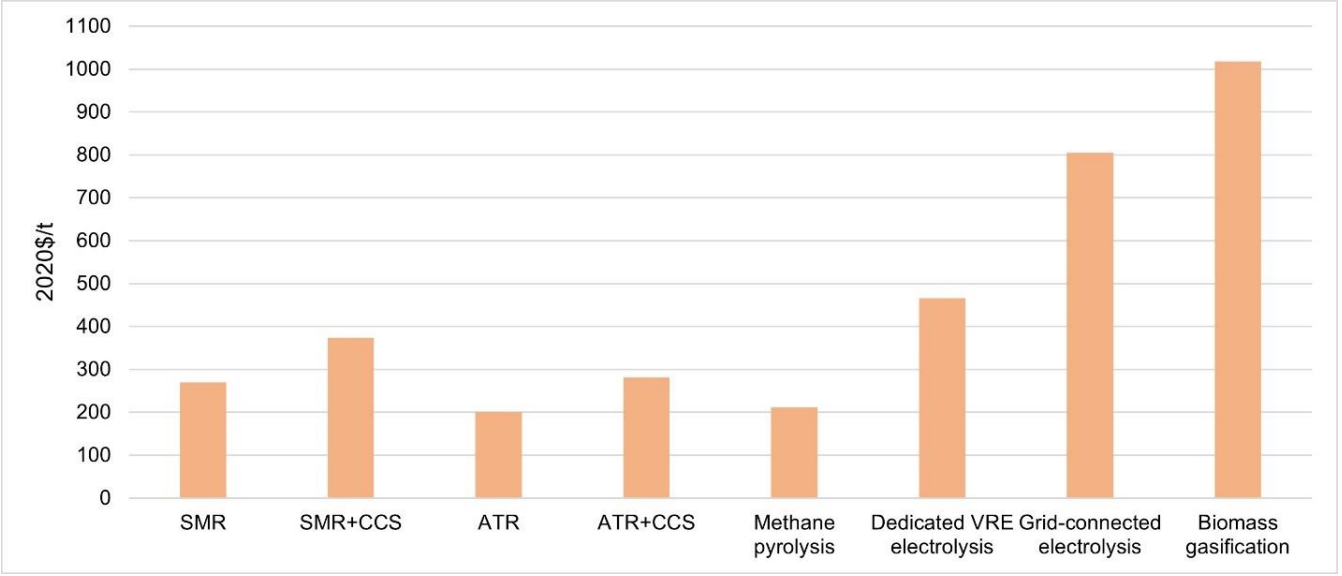
Decarbonization of U.S. ammonia Industry



Low emission technologies are ~10-100% more expensive per ton of produced ammonia compared to current pathways

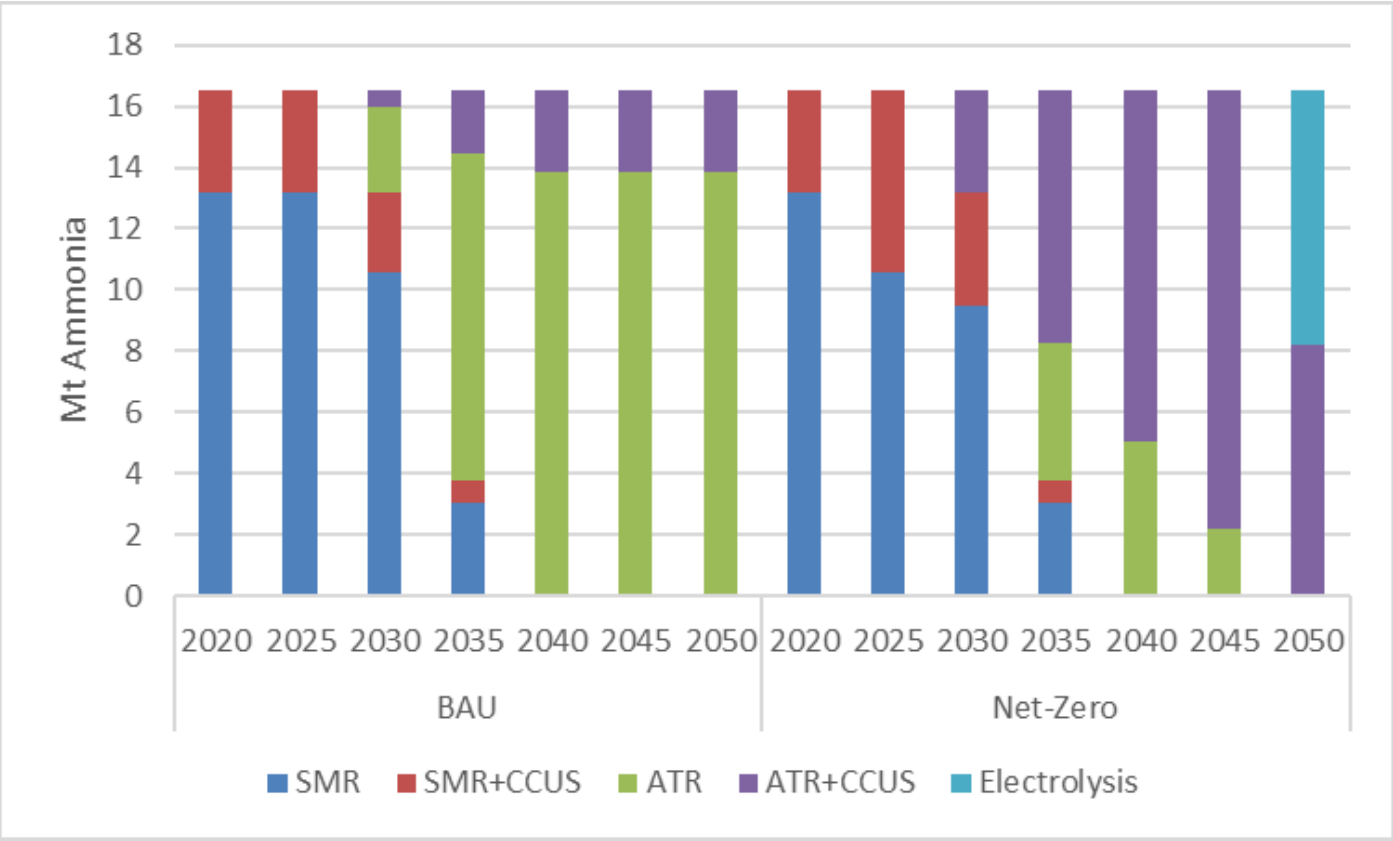
TIMES modeling scenarios

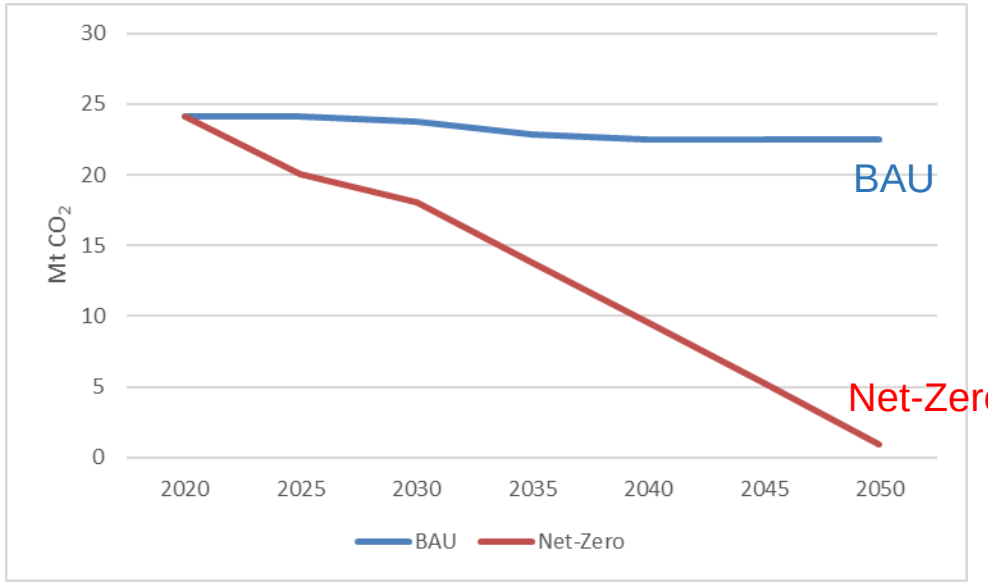
- BAU: no mitigation actions
- Net-Zero: 95% direct emission reduction by 2050

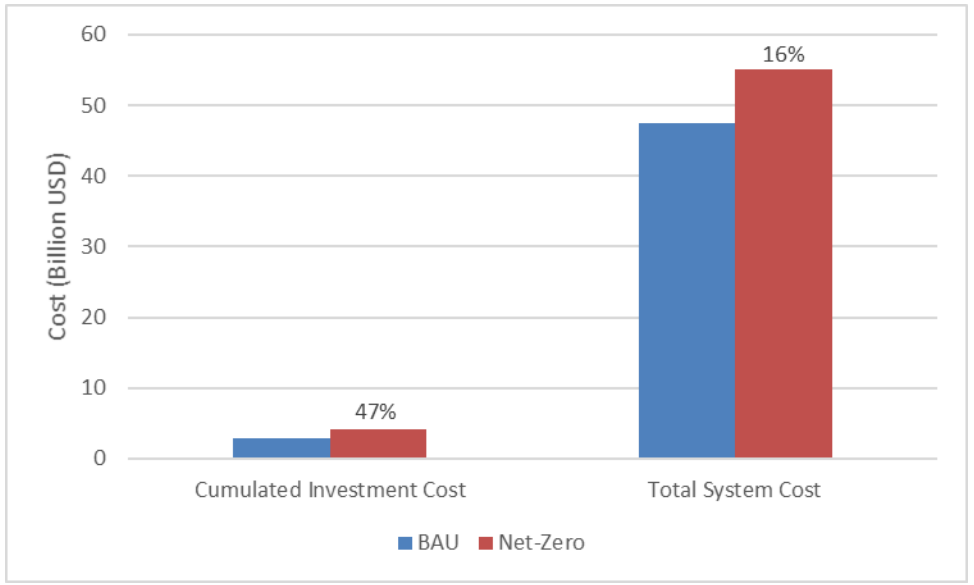


Levelized cost of U.S. ammonia production by process routes in 2020

Path to Net-Zero U.S. ammonia







BAU (no mitigation actions)

- Production mainly based on unabated NG-based pathways
- Switch to ATR after SMR plants retirement by 2040

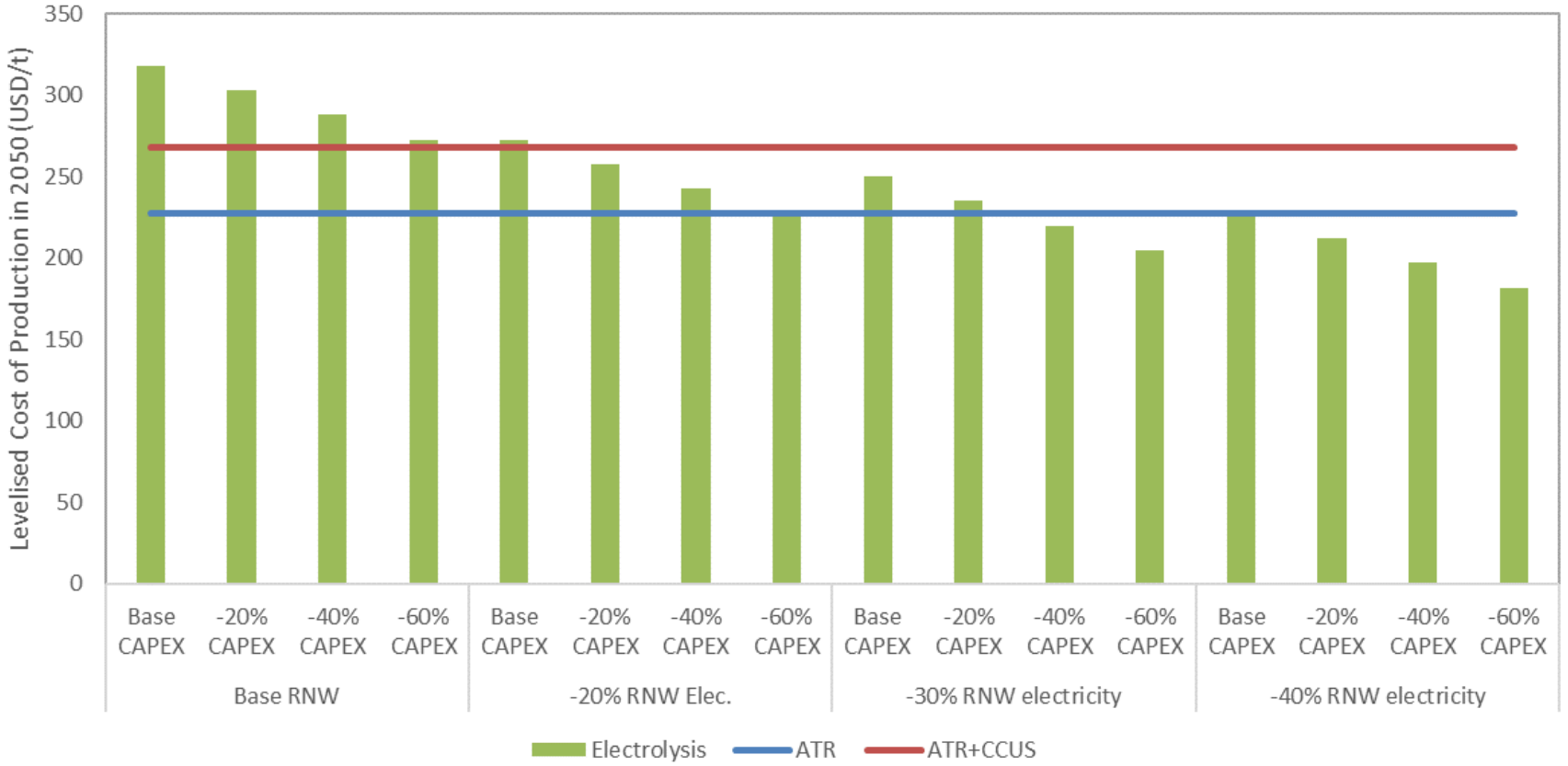
Net-Zero scenario

- CCUS-equipped installations play the key role by 2045
- Water electrolysis contributes for ~50% of production in 2050

Current Issue: Tipping points identification to induce the transition towards Net-Zero

Identify key economic and technical parameters affecting the cost of low-carbon ammonia

- Investment costs, CAPEX, of innovative technologies
- Resource prices (fossil fuels and renewable electricity)
- Performance efficiency



Multi-dimensional Sensitivity Analysis?