Low-Pressure Electrolytic Ammonia (LPEA) Production

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University of North Dakota (UND) Energy & Environmental Research Center (EERC)

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Overview

Timeline

- LPEA Award issued June 2018
- Projected End date June 2021
- Project 0% complete

Partners

- University of North Dakota (UND) Energy & Environmental Research Center (EERC)
- North Dakota State University
- UND Chemistry
- Proton OnSite

Budget

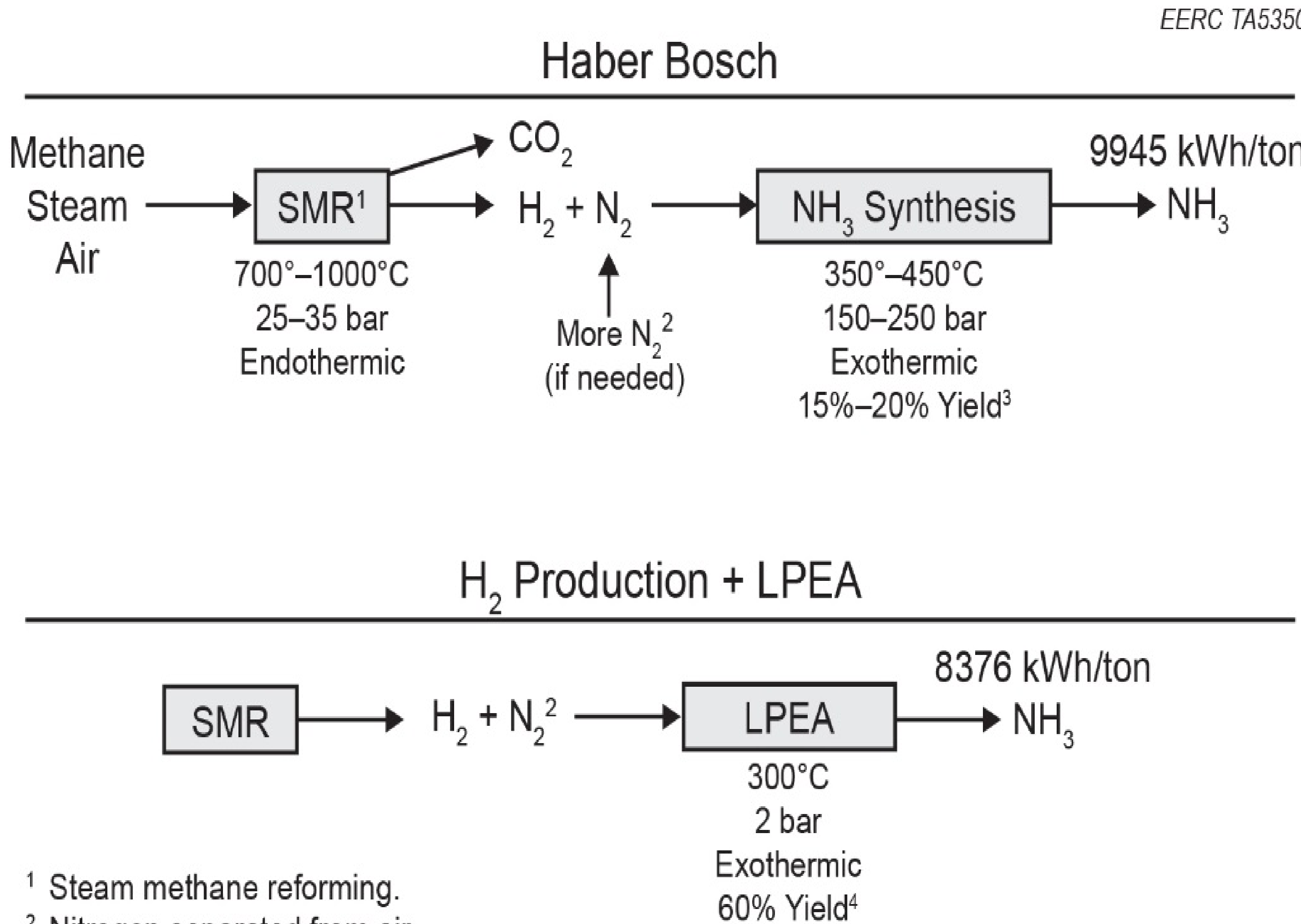
	BP1 (18 Months) Costs	BP2 (18 Months) Costs	Total Project Funding
DOE Funded	$1.4M	$1.1M	$2.5M
Project Cost Share	$370K	$300K	$670K

Project Objective

- Haber Bosch- (HB-) based processes need high pressure (1100–3000 psi) to achieve economically viable ammonia yields (15%–18% based on single-pass hydrogen conversion).
- High pressure translates to:
  - High capital/operating costs (need to compress both new and recycled reactants).
  - High energy consumption and CO_2 emissions.
- LPEA use of electricity as driver enables control of ammonia formation reaction on catalyst surface, eliminating need for high pressure.

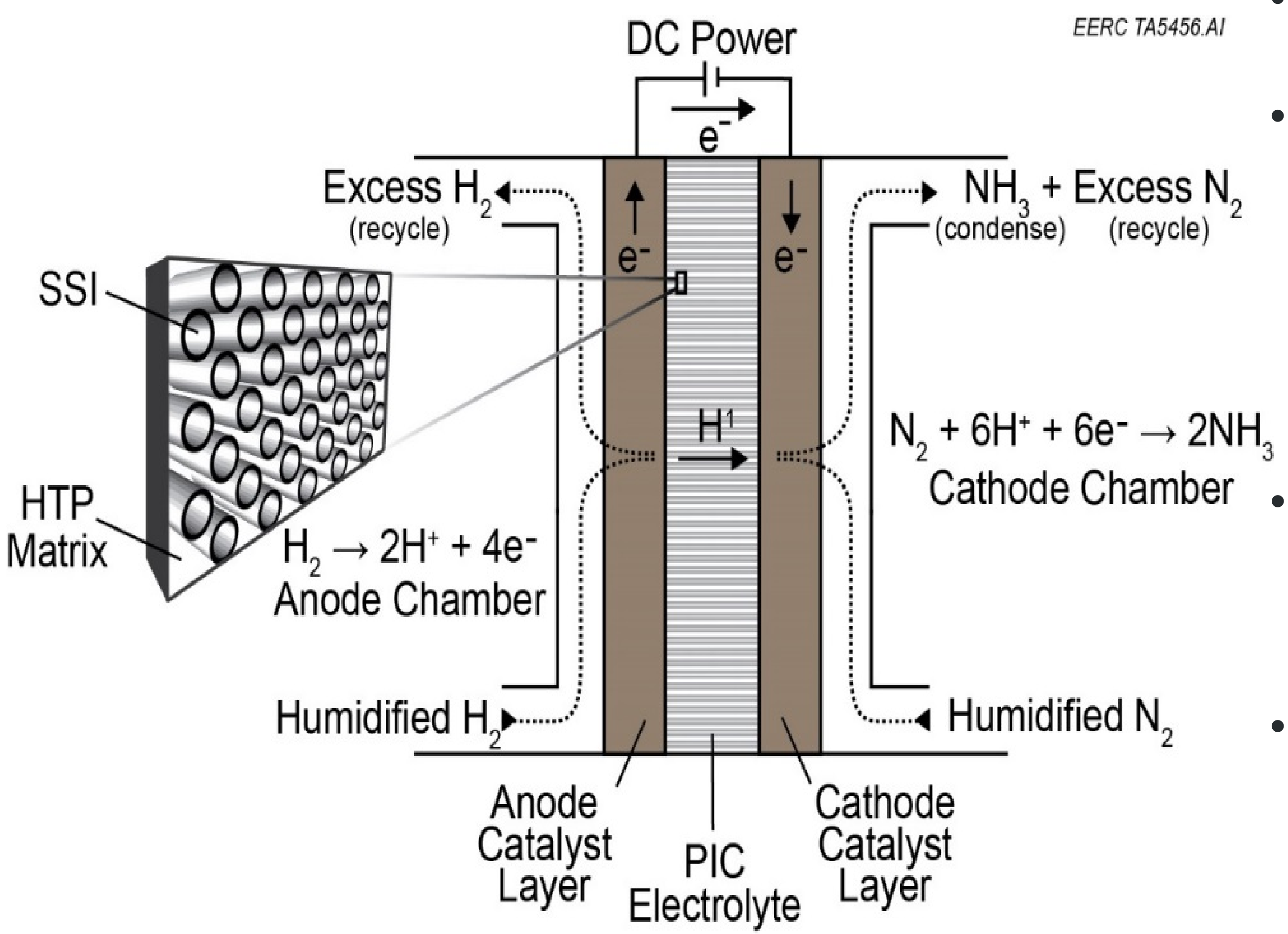
- Project Goal – Optimize LPEA process to achieve 16% production energy input reduction versus HB-based processes—9945 to 8376 kWh/ton NH_3.
  - Key to achieving goal is optimization of high-temperature (300–350°C) high-proton-conductivity gas-impermeable polymer–inorganic composite (PIC) proton exchange membrane.

Technical Innovation – LPEA versus HB



[1] Steam methane reforming.
[2] Nitrogen separated from air.
[3] Single-pass yield based on hydrogen conversion.
[4] Targeted single-pass yield based on current efficiency of 65% at current density of 0.25 A/cm^2.

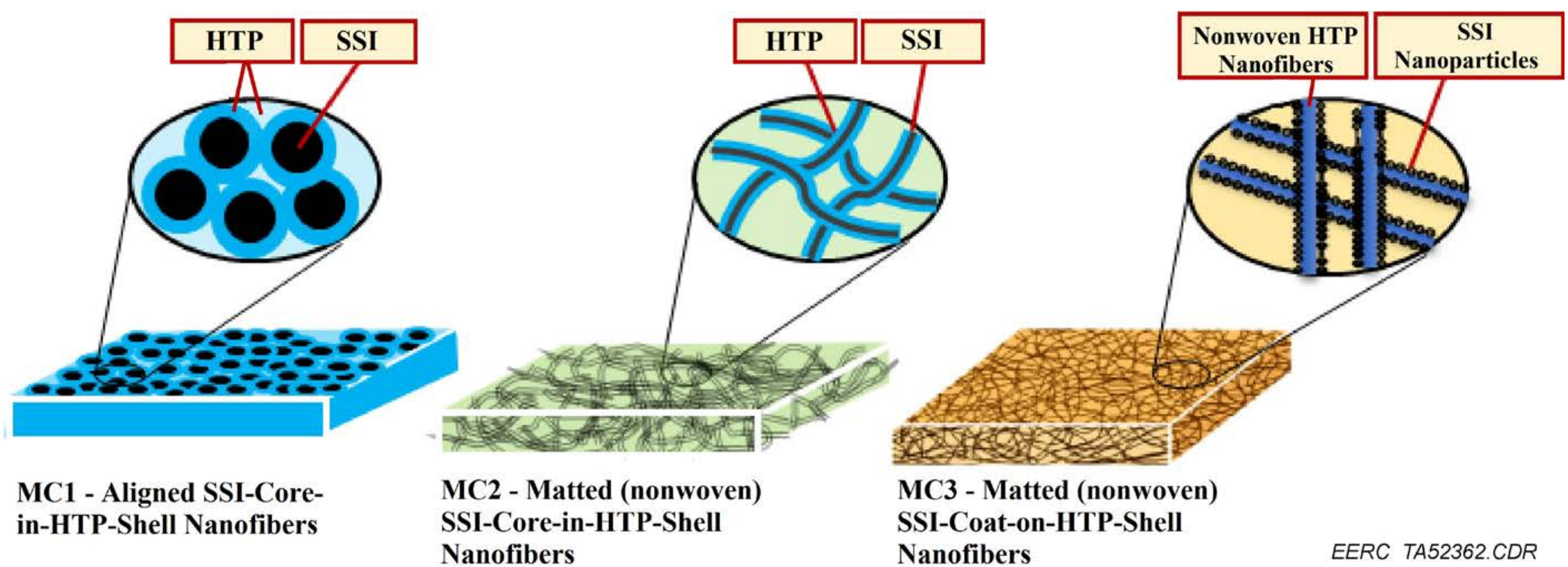
Technical Innovation – LPEA Process



- EERC-patented process based on PIC membrane.
- Advanced compositing process yields SSI inorganic proton-conducting nanofibers contained within and perpendicularly aligned to plane of high-temperature polymer (HTP) matrix.
- Resulting PIC membrane is gas-tight with high-proton-conductivity at 300°C operating temperature.
- Key LPEA performance attributes:
  - Turn on/off capability
  - Modularity/scalability
  - Solid state simplicity

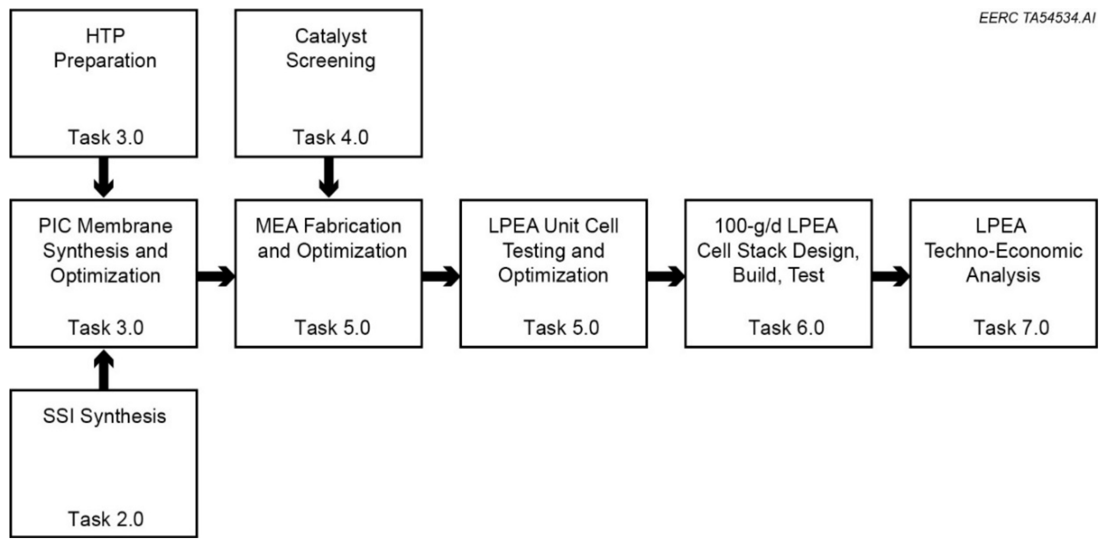
Technical Approach

- Optimize SSI proton-conducting inorganic particles
- Optimize advanced compositing method for fabricating PIC Membrane Configuration 1 (MC1) based on SSI and high-temperature polymer
  - If MC1 unachievable, move to lower risk MC2, and MC3, if needed
- Screen and select cathode catalyst(s)
- Using PIC membrane and selected catalysts, manufacture membrane electrode assemblies (MEAs)
- Design, fabricate, operate 100-g/day LPEA system
- Perform LPEA techno-economic analysis, develop commercialization plan

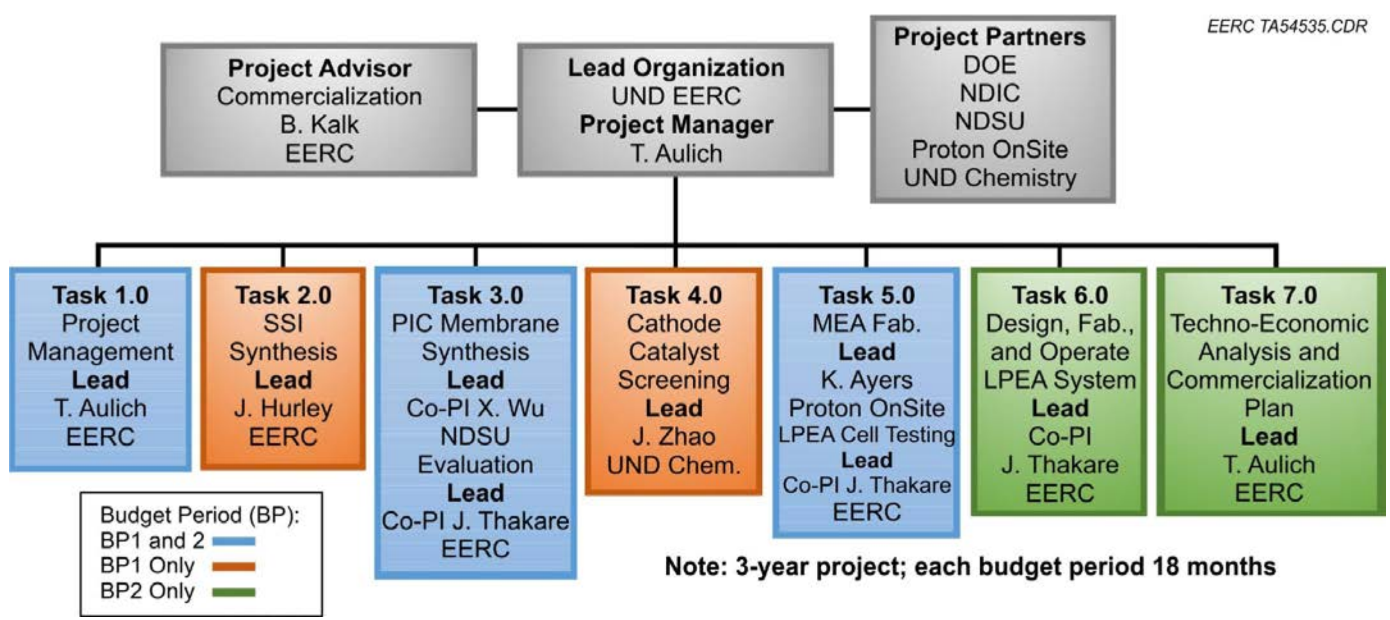


Technical Approach

Project Work Flow (top)



Team Responsibilities (bottom)



Technical Approach

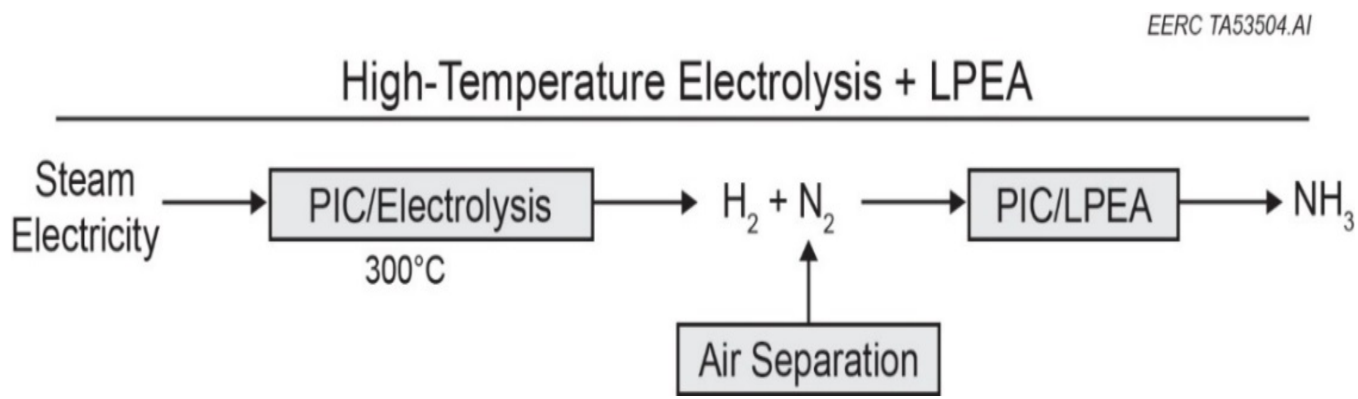
PIC proton exchange membrane performance targets

- Proton conductivity of ≥10^{-2} Siemens/centimeter at 300°C
- Gas permeability of <2% at 300°C
- Ability to sustain 10^{-2} Siemens/centimeter proton conductivity for at least 1000 hours
- Mechanical strength (at 300°C) comparable to that of commercial PEM electrolyzer membrane
- As measured in membrane–electrode assembly (MEA) at minimum temperature of 300°C:
    - Current efficiency of ≥65% for ammonia formation at current density of ≥0.25 amps/centimeter^2*
    - Ammonia production efficiency of ≥65%*
    - ≤0.3% performance degradation per 1000 hours operation*

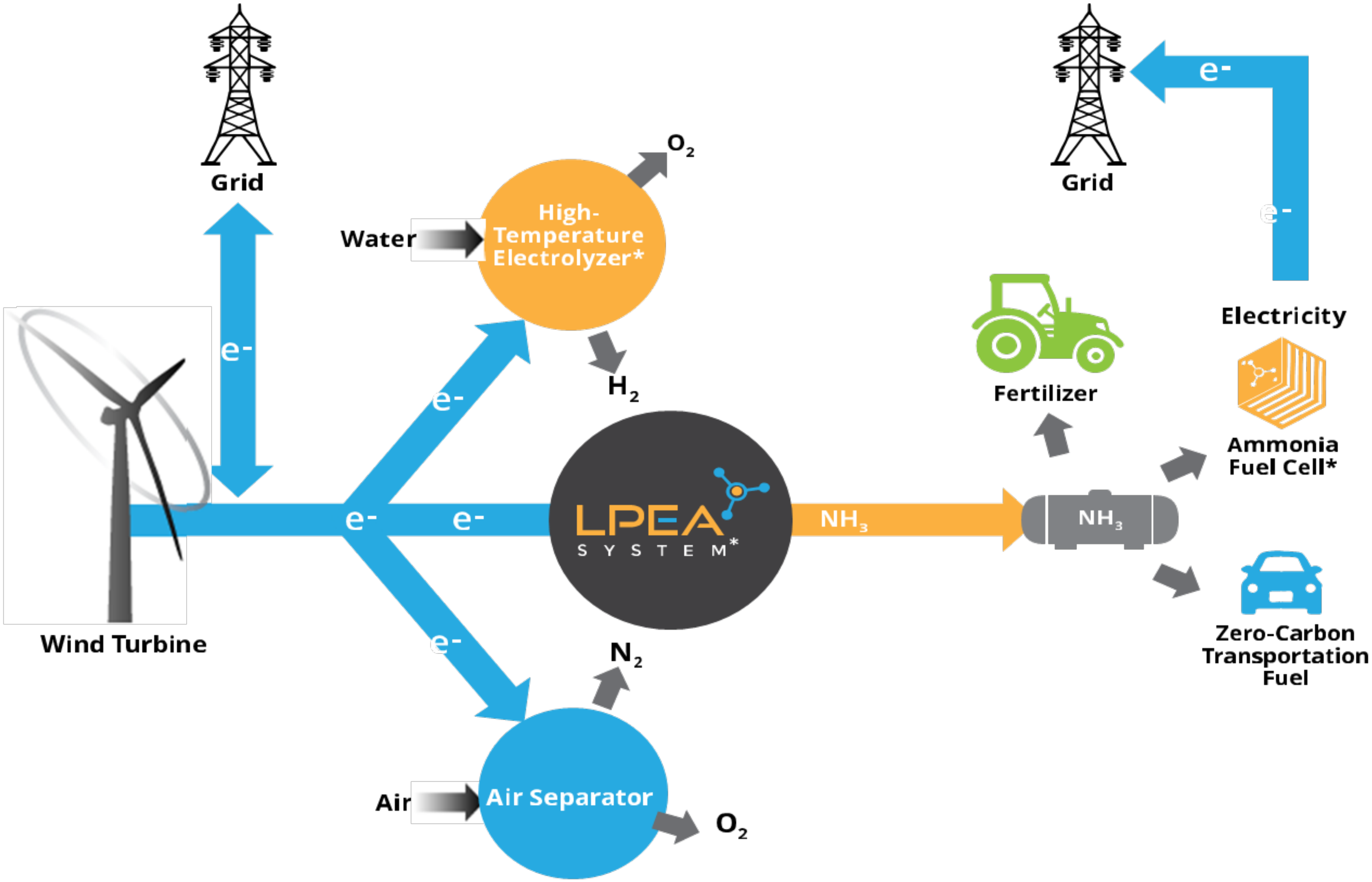
*** U.S Department of Energy-specified performance target**

Transition (beyond DOE assistance)

- Use techno-economic analysis results to secure arrangements with North Dakota utility or ammonia production facility for LPEA pilot-scale demo.
- Use demo results to negotiate nonexclusive licenses with engineering/design firms that service ammonia, chemical, power industries
- Use demo results to market LPEA as:
  - Option for integration into existing ammonia supply chain to replace portions of and/or supplement current HB infrastructure.
  - Means for monetizing renewable energy and/or utilizing low-cost off-peak power.
- PIC membrane may also be applicable to high-temperature low-energy electrolysis for hydrogen production (below).



The Future: Ammonia Economy



*Technology based on EERC–NDSU-developed polymer-inorganic composite (PIC) electrolytic membrane.

Questions?