Low-Pressure Electrolytic Ammonia (LPEA) Production via Polymer–Inorganic Composite (PIC) Membrane

EERC

Critical Challenges. Practical Solutions.

NH3 Fuel Association Annual Conference
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Project Partners

PROTON
THE LEADER IN ON SITE GAS GENERATION.

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U.S. DEPARTMENT OF ENERGY
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ENERGY EFFICIENCY & RENEWABLE ENERGY

renewable ENERGY PROGRAM
NORTH DAKOTA INDUSTRIAL COMMISSION

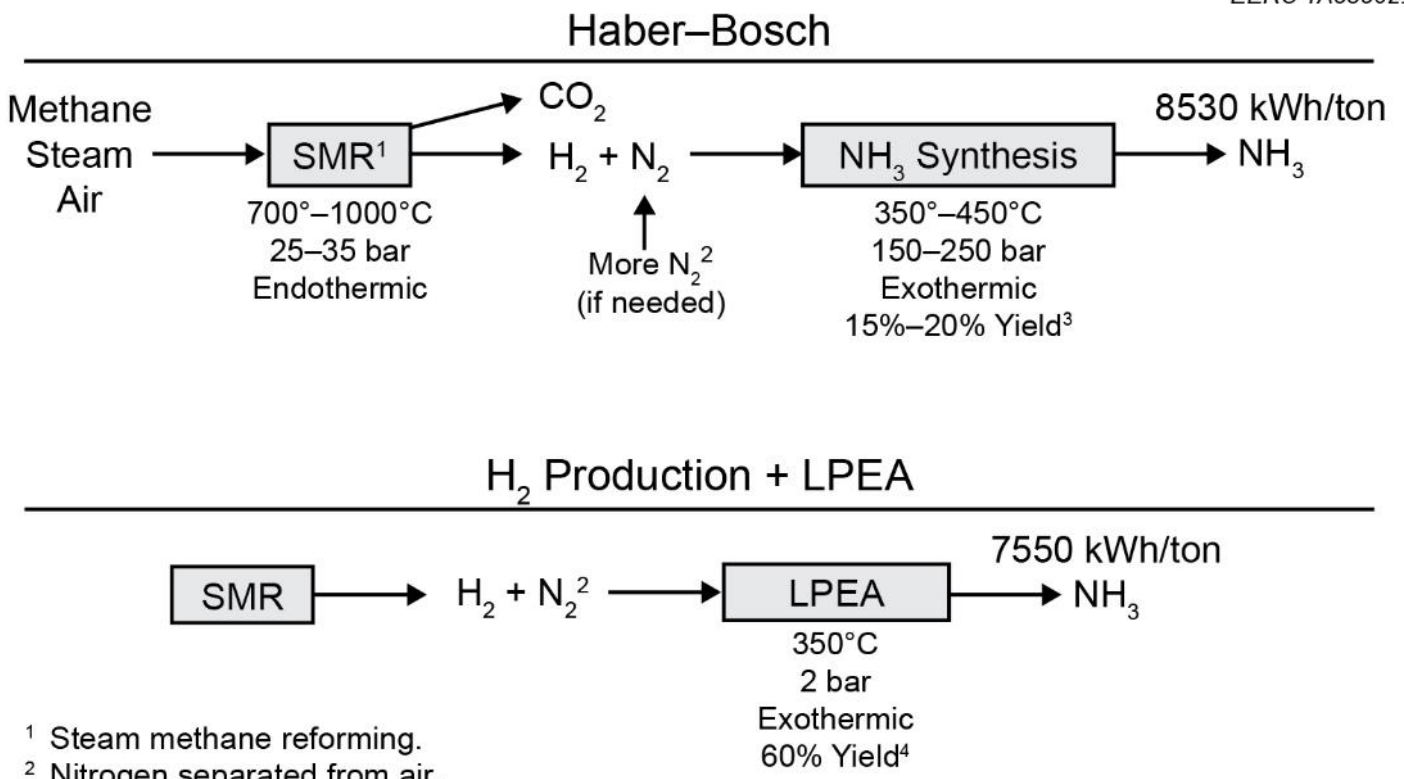
Project Goals

Demonstrate at least 12% LPEA energy input reduction versus HB-based processes: 8530 to 7550 kWh/ton NH_3

Demonstrate LPEA reduced capital/operating cost and turn down/on/off flexibility

Key to achieving goals is high-temperature (350°C) high-proton-conductivity gas-impermeable polymer–inorganic composite (PIC) proton exchange membrane

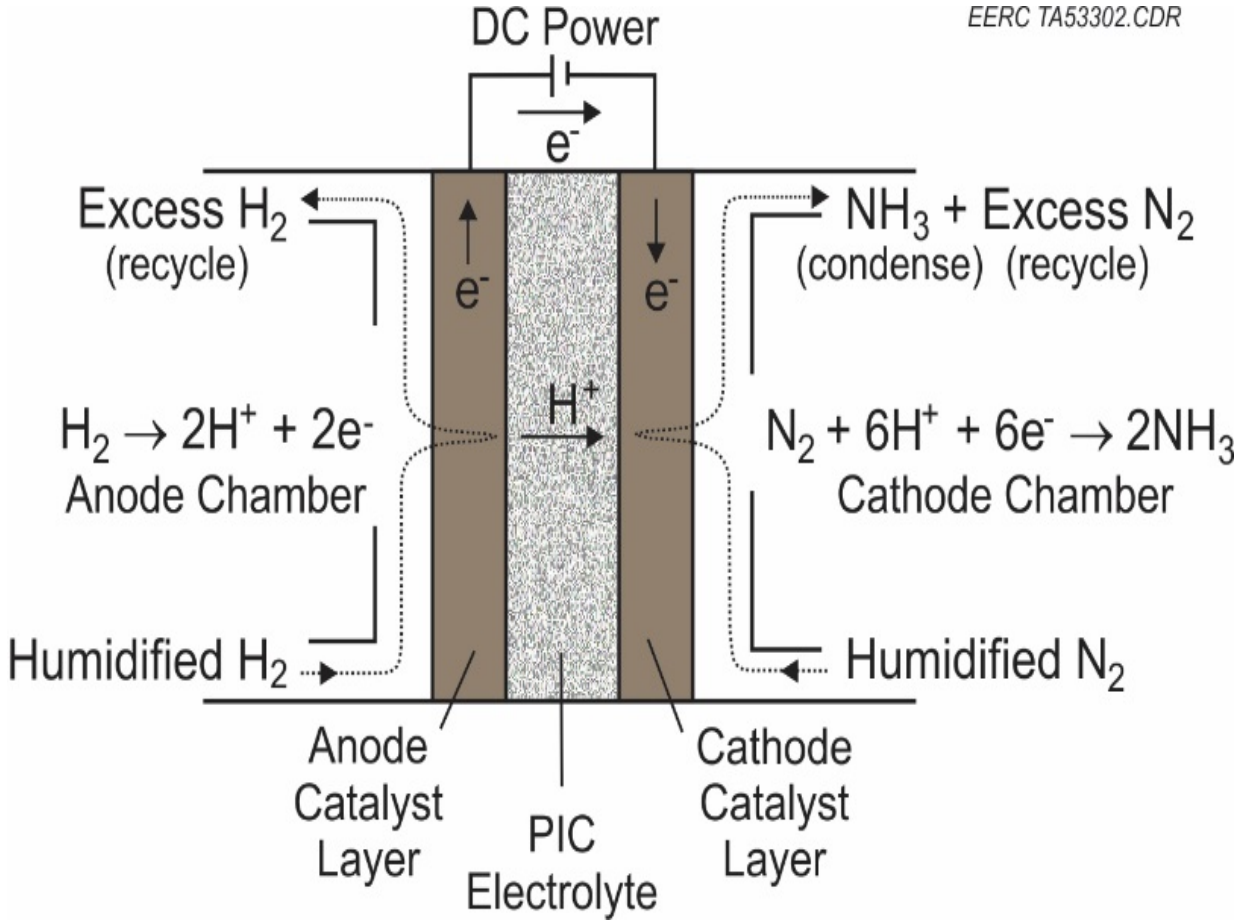
EERC TA53502.AI



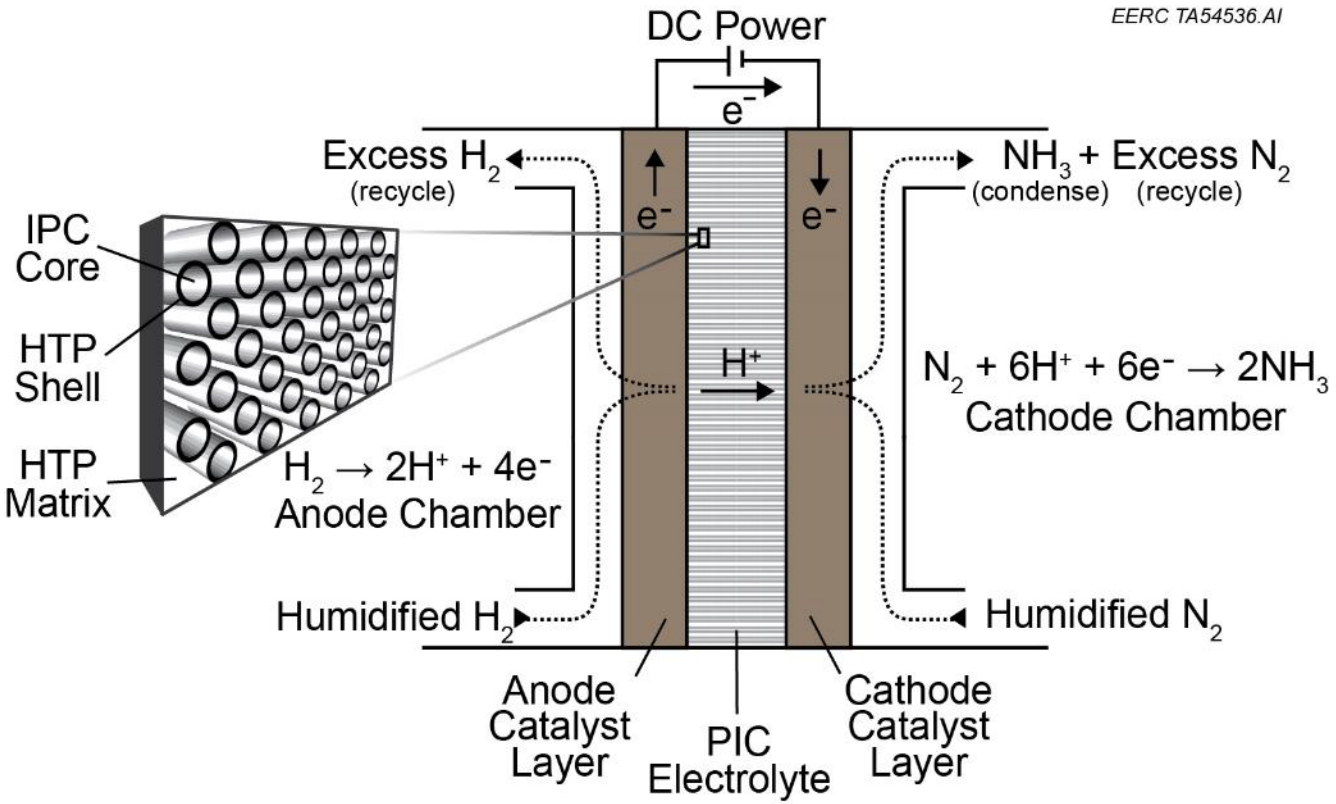
[1] Steam methane reforming.
[2] Nitrogen separated from air.
[3] Single-pass yield based on hydrogen conversion.
[4] Targeted single-pass yield based on current efficiency of 65% at current density of 0.25 A/cm^2.

Patented LPEA process based on initial PIC membrane

- EERC developed and patented
  - U.S. Patent 9,005,422 B2
  - U.S. Patent 8,152,988
- Based on PIC membrane, which comprises:
  - Inorganic proton conductor material capable of 10^{-2} siemens/centimeter (S/cm) proton conductivity at 350°C
  - High-temperature polymer matrix for gas-tight seal
- Key LPEA performance attributes
  - Solid state simplicity
  - Economic turn down/on/off capability
  - Modularity/scalability



Advanced PIC Membrane



- Advanced compositing process yields nanofibers comprising “core” of inorganic proton conductor (IPC) and “shell” of high-temperature polymer (HTP)
- Core–shell IPC–HTP nanofibers aligned within HTP matrix function as proton-conducting “wires”
- Resulting PIC membrane is gas-tight with high-proton-conductivity at 350°C operating temperature, required for commercially relevant NH3 production rate

PIC Proton Exchange Membrane Performance Targets

- Proton conductivity of ≥10^{-2} siemens/centimeter (S/cm) at 350°C
- Gas permeability of <2% at 350°C
- Ability to sustain 10^{-2} S/cm proton conductivity for at least 1000 hours
- Mechanical strength (at 350°C) comparable to that of commercial PEM electrolyzer membrane
- As measured in membrane–electrode assembly (MEA) at 350°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*

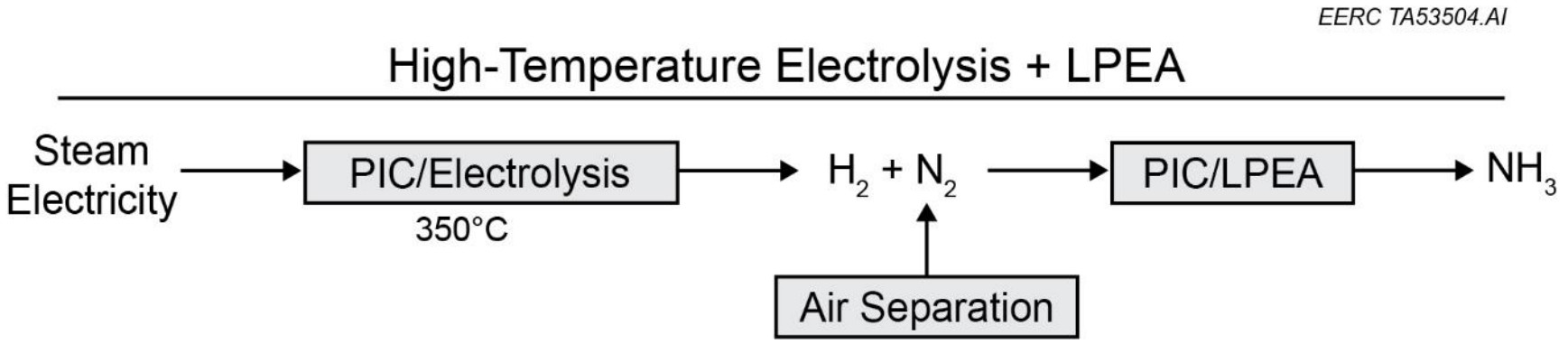
*** U.S Department of Energy-specified performance target**

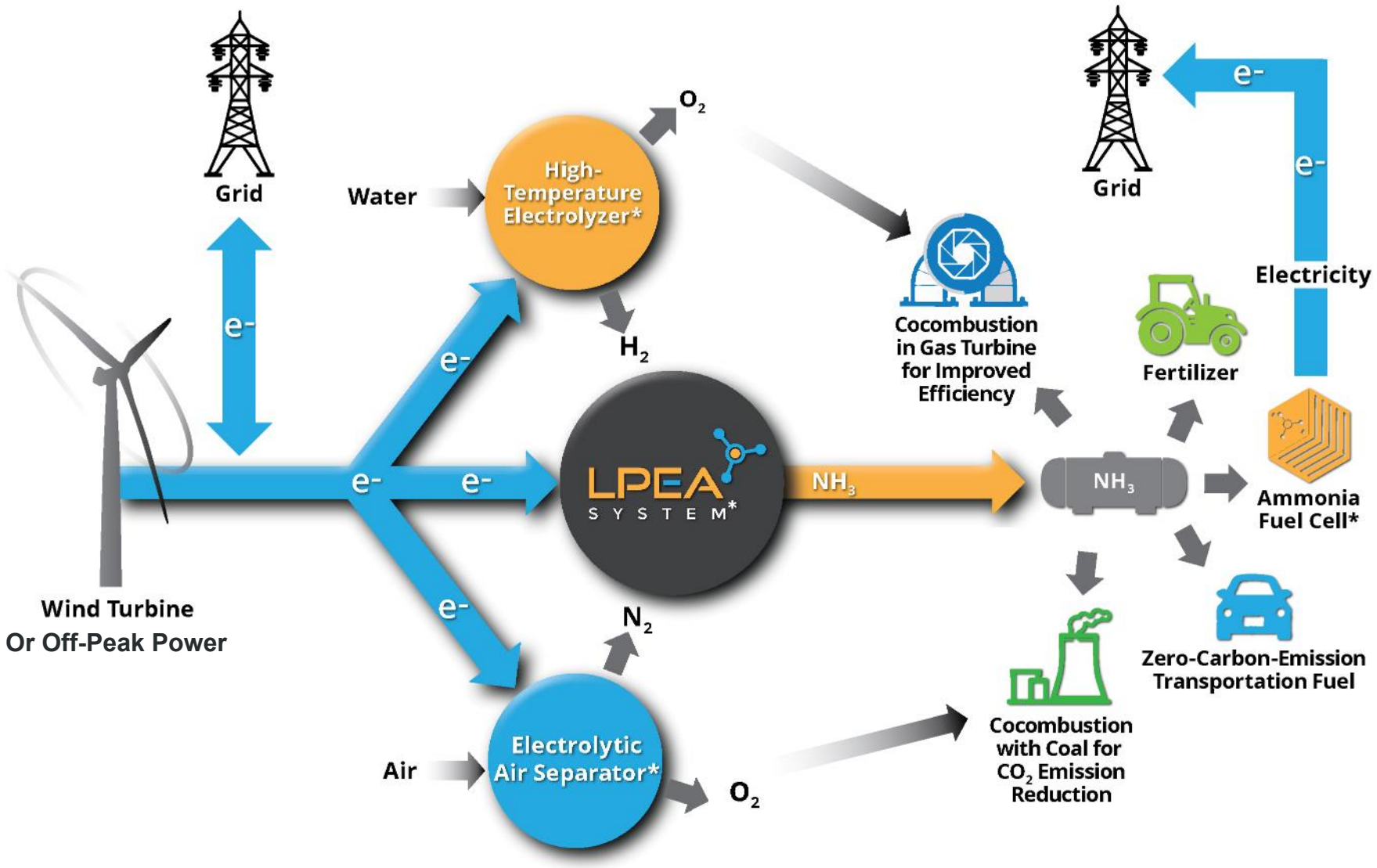
LPEA Techno-Economic Evaluation

- Establish LPEA input energy requirement based on results of extended system operation tests (minimum 12% reduction versus HB is targeted)
- Derive (from project data) complete LPEA system capital and operating cost estimates (on per-annual-ton-ammonia-production-capacity basis) at distributed scales selected to match renewable energy generation capacities specified by North Dakota utilities
- Project overall per-ton ammonia production costs at selected North Dakota locations
- Compare LPEA per-ton cost with per-ton cost of HB-produced delivered ammonia

Commercialization

- 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)





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

Ammonia:

Fuel and Fertilizer

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