

Fed. funding:	\$1.985M
Length	36 mo.

# Electrochemical Ammonia Synthesis for Grid Scale Energy Storage

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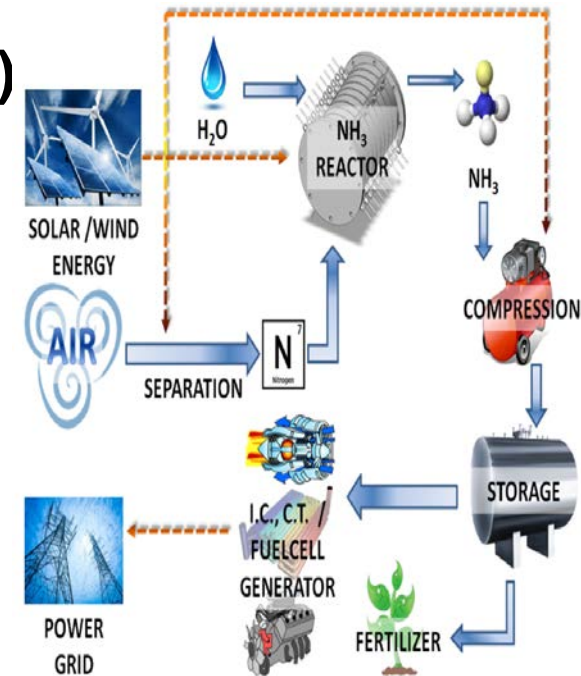
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## Project Vision

- Higher efficiency solid electrolyte membrane based process to synthesize ammonia
- Technology allows synthesis of carbon free ammonia and integration for storage in low cost steel vessels for long term energy storage

## Project Impact

- Process runs efficiently on small scales compared to H-B process
- Facilitates renewable electrical energy into high energy liquid fuel, greatly increasing ability to store GWhr of energy on-site



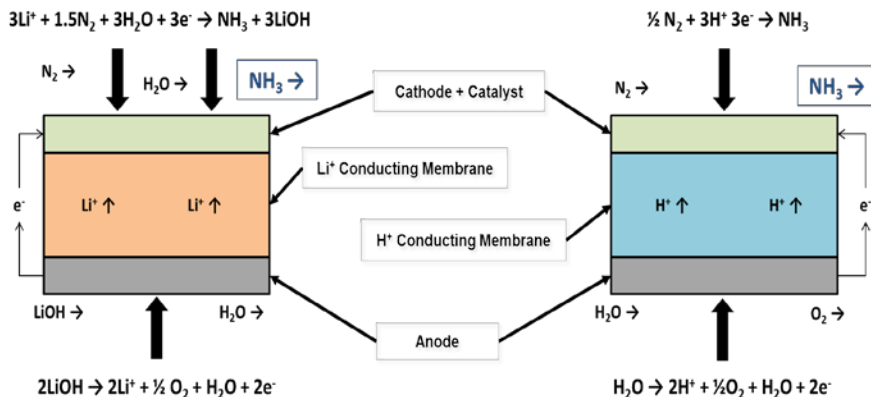
# Innovation and Objectives

## Innovation

Synthesis of  $\text{NH}_3$  at moderate temperatures ( $< 350^\circ\text{C}$ ) and pressures ( $< 0.5 \text{ atm.}$ ).

Electrochemical synthesis of  $\text{NH}_3$  from  $\text{H}_2\text{O}$  or  $\text{H}_2$  provides most direct and theoretically efficient process.

Storage of electrical energy in chemical bonds that can be back converted to electricity.



## Task outline, technical objectives

- Develop  $\text{Li}^+$  and  $\text{H}^+$  solid electrolytes process for  $\text{NH}_3$  synthesis.
- ✓ Demonstrate an ammonia synthesis rate of  $10^{-8} \text{ mol}_{\text{NH}_3} \cdot \text{cm}^{-2} \cdot \text{s}^{-1}$  at current efficiency  $> 70\%$  Demonstrate prototype 3-cell stack
- ✓ Establish overall system cost for 162 MT/day of ammonia for grid storage

## Tech-to-Market strategy

Ammonia for fertilizer, transportation fuel, generation of electricity for peak requirements. Early market would be wind farms located on farmland with limited grid connectivity. Large volume manufacturing of solid electrolytes at parent company CoorsTek. Supply chain established to build modular reactors for  $\text{NH}_3$  synthesis.

# Innovation and Objectives

## Project history

- Concept for ammonia synthesis using Li<sup>+</sup> membrane process developed at Ceramatec.
- Preliminary research on H<sup>+</sup> exchange membrane/catalyst developed @ LANL for electrochemical processes adapted for NH<sub>3</sub> synthesis.
- Ceramatec and LANL have teamed on prior projects.

## Proposed targets

Metric	State of the Art	Proposed
Energy/ ton of NH <sub>3</sub>	>10.5MW-hr/ton	<7.5MW-hr/ton
Plant Size Economics	~4000 MT/day (<150 MT/day-\$53 M)	1-10- <b>150</b> MT/day (\$ 43M)
reactor Temp	500-650° C	150-300° C

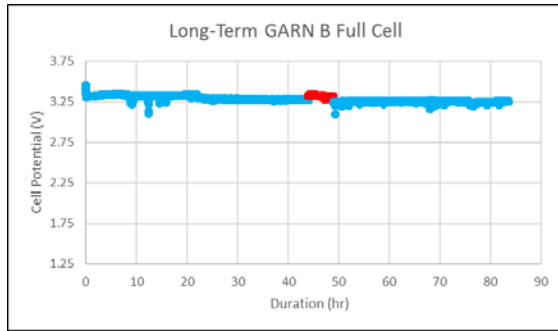
## Anticipated challenges

- Li<sup>+</sup> and H<sup>+</sup> membranes to maintain conductivity (> 20 mS/cm).
- Nitrogen (N<sub>2</sub>) splitting catalysts for H<sup>+</sup> process are not efficient.
- Energetic losses in catalyst layer lowers H<sup>+</sup> process efficiency < 70%

## Desirable partnerships

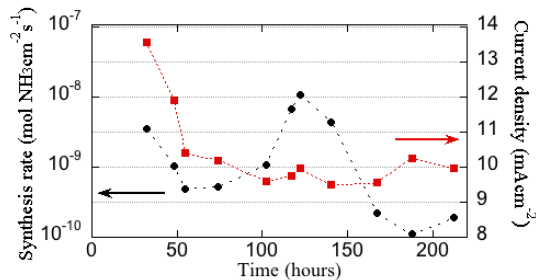
- Review early stage adaption of technology.
- Evaluate round trip efficiency/process economics for long term storage.
- Develop foot print @engineering scale pilot.

# Technical Progress



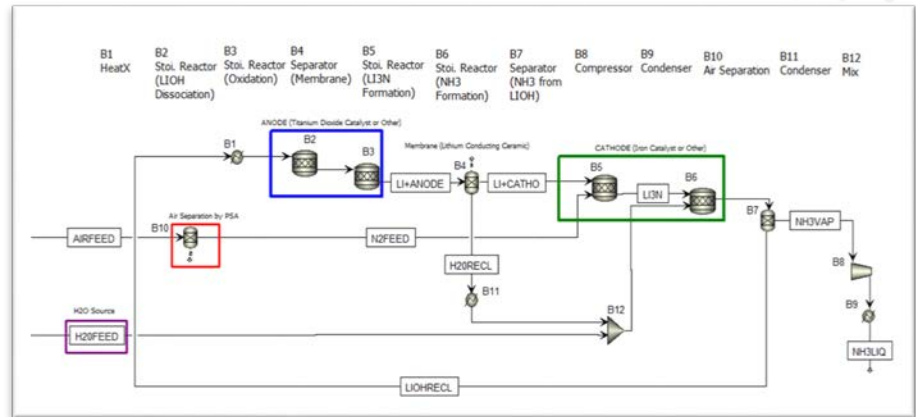
Li cell operated-23.5mAh  
 $\text{NH}_3$  synthesis @  $1.31 \times 10^{-8}$  mol  $\text{NH}_3/\text{cm}^2/\text{s}$  @  
 76% conversion efficiency demonstrated.

130mm 90%TPP|Ionomer|Pt GDE



Proton cell: Synthesis rates of  $10^{-10}$ - $10^{-8}$  mol  $\text{NH}_3 \text{ cm}^{-2}\text{s}^{-1}$  obtained  
 Variation in current density and production rate being investigated

## Aspen Modeling



Li<sup>+</sup> process for ammonia synthesis