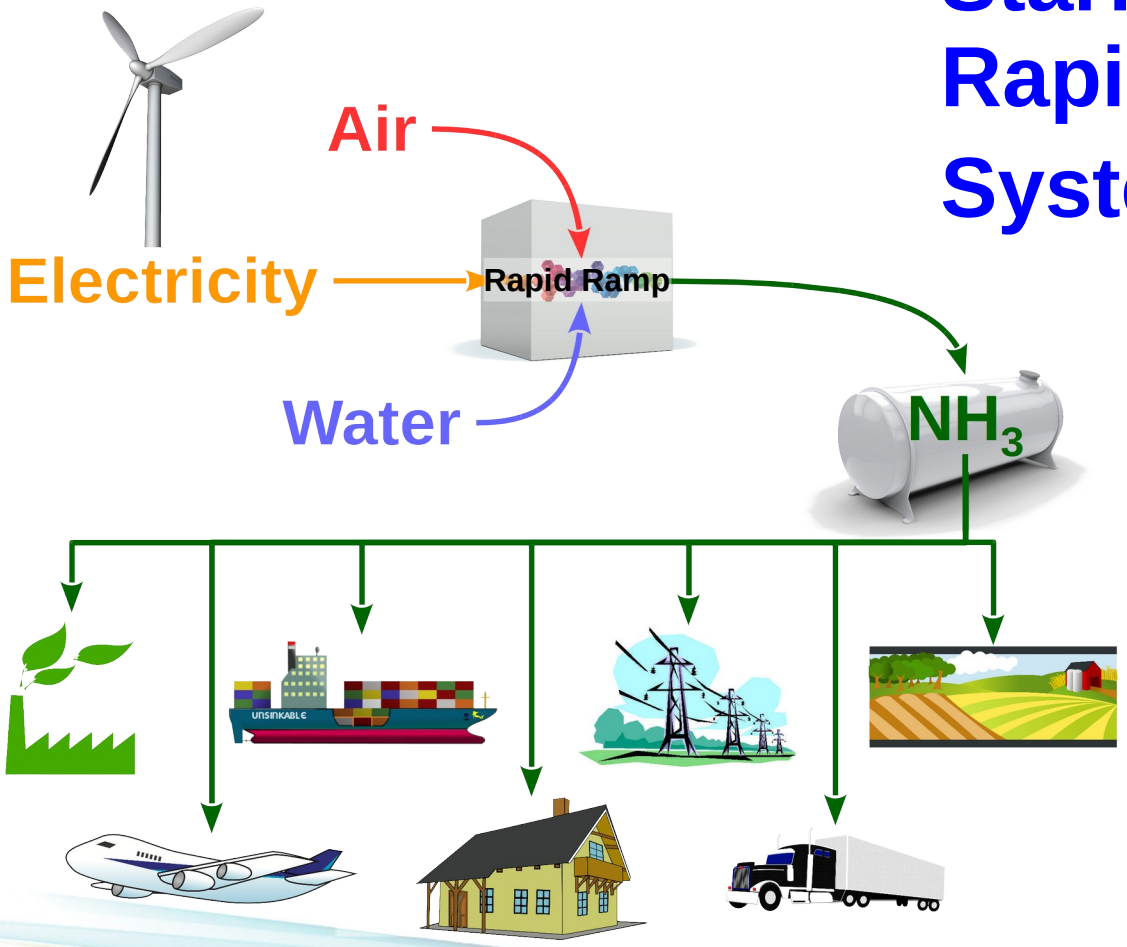
Starfire Energy's 10 kg/day Rapid Ramp NH_3 System Development



Starfire Energy Inc
Joe Beach, CEO

Funded by
ARPA-E 2015 Open # DE-AR0000685
DOE SBIR # DE-SC0019846
Colorado OEDIT # CTGG1 19-3593

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Starfire Energy is a clean energy company

- Research, development, deployment
- Solar, hydrogen, business background
- 7 full-time, 2 part-time staff

Clean power plants into clean fuel factories

New US Great Plains wind

- $0.012 – $0.020/kWh
- 50% – 65% capacity factor

New US Southwest solar

- $0.04 - $0.07/kWh
- 20% - 30% capacity factor

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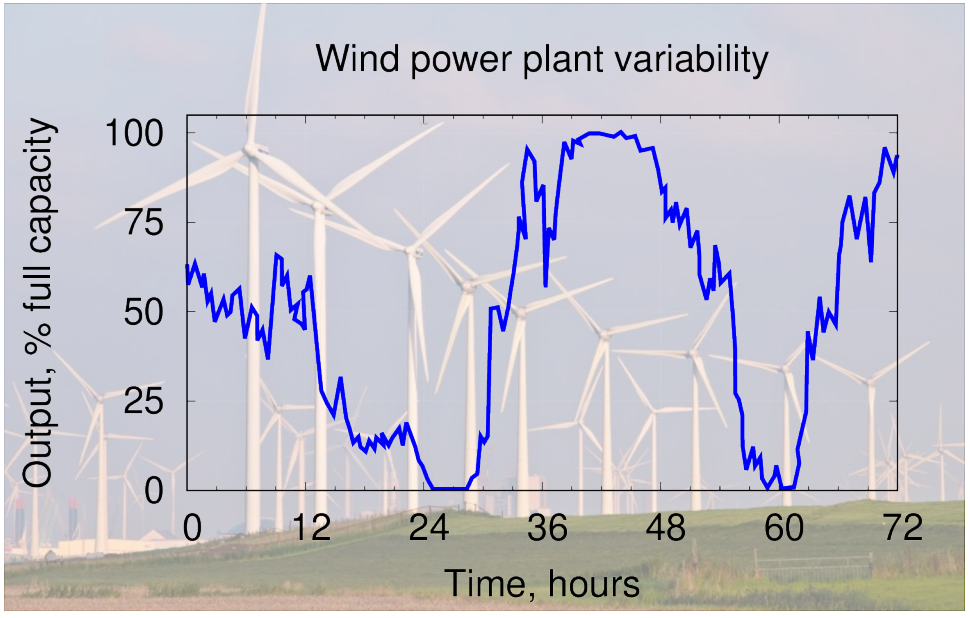
Fuel synth. must mesh with variable power



New US Great Plains wind

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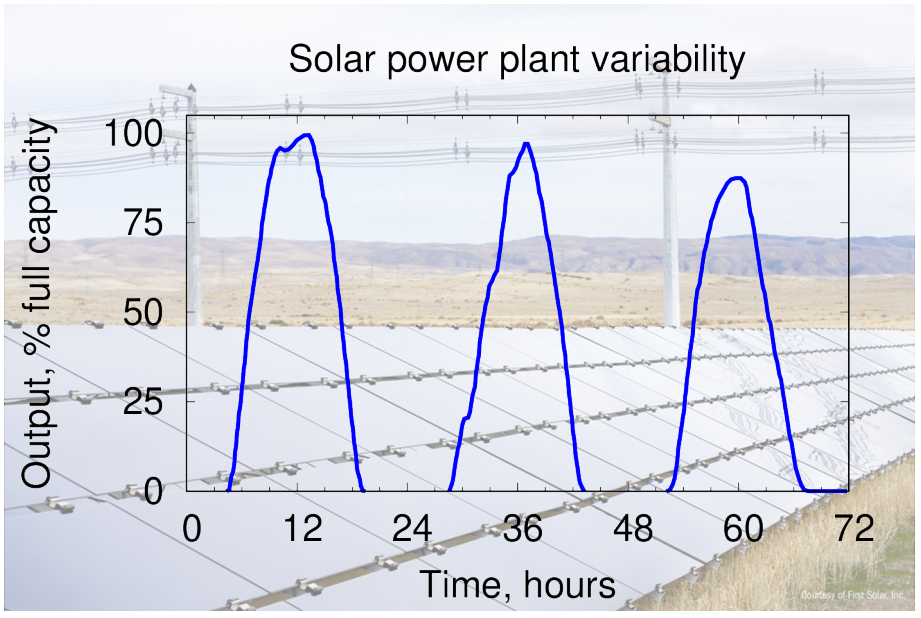

New US Southwest solar

- $0.04 - $0.07/kWh
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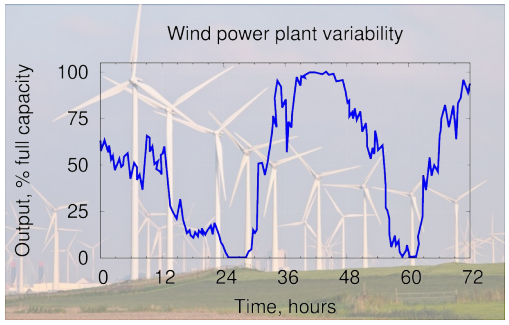
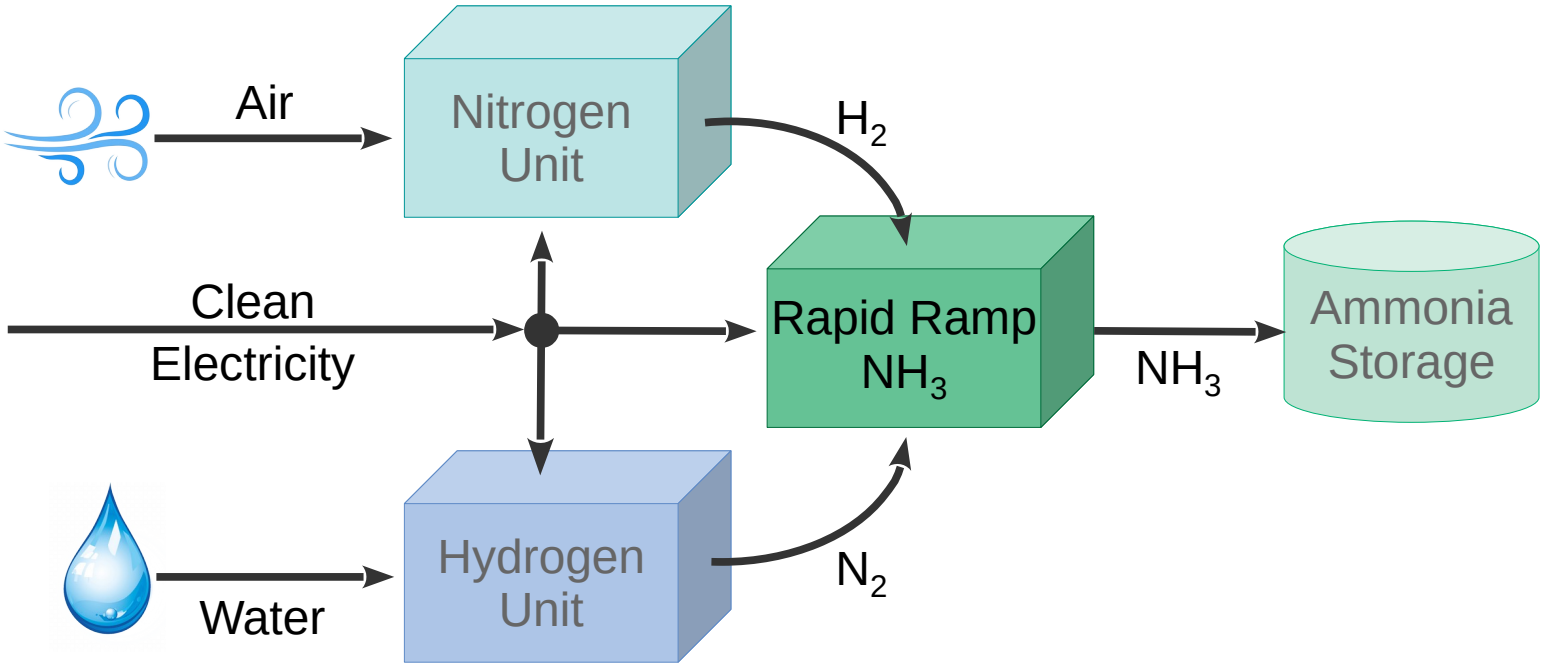
“Rapid Ramp NH_3”: flexible ammonia synth.





- N_2 and H_2 used as they are made
- No massive reactant buffering

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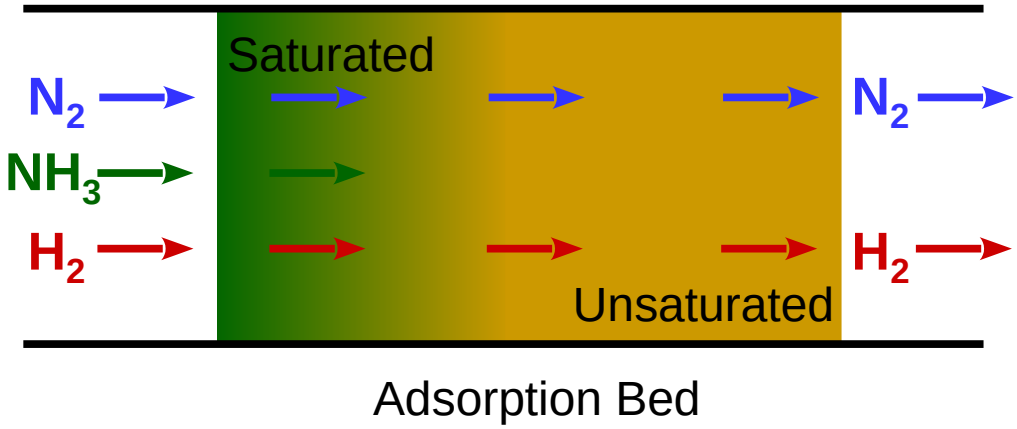
Monolith catalyst & NH_3 adsorption are key



Adsorption Bed

Monolith catalyst

- High catalyst utilization
- Near-zero pressure drop

NH_3 adsorption removal

- No liquefaction constraints
- Any reactor P or T

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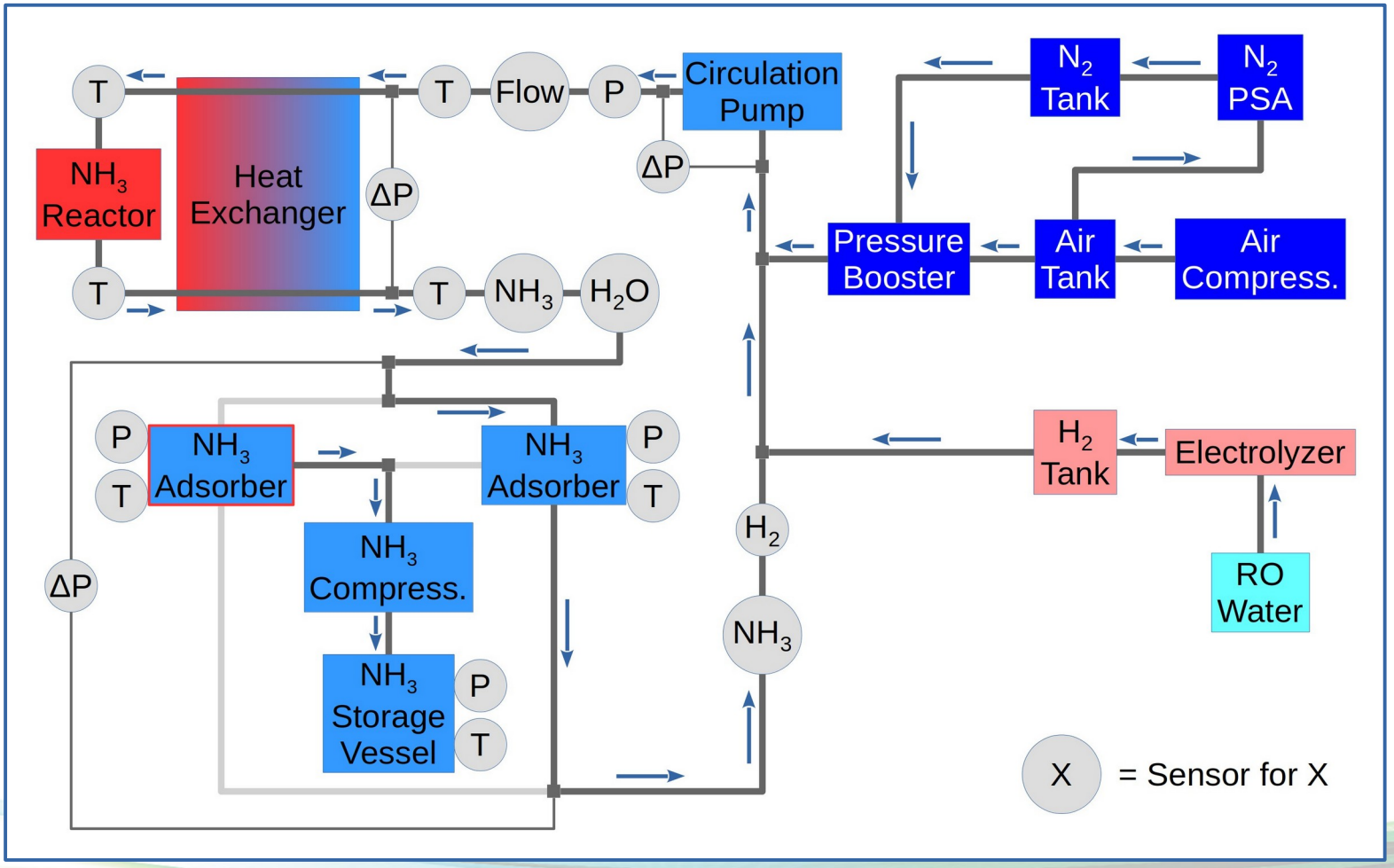
Implementing process in 10 kg/day system



- PSA nitrogen
- AEM hydrogen
- 30 bar e-chem H_2 compress.
- Pneumatic N_2 press. boost

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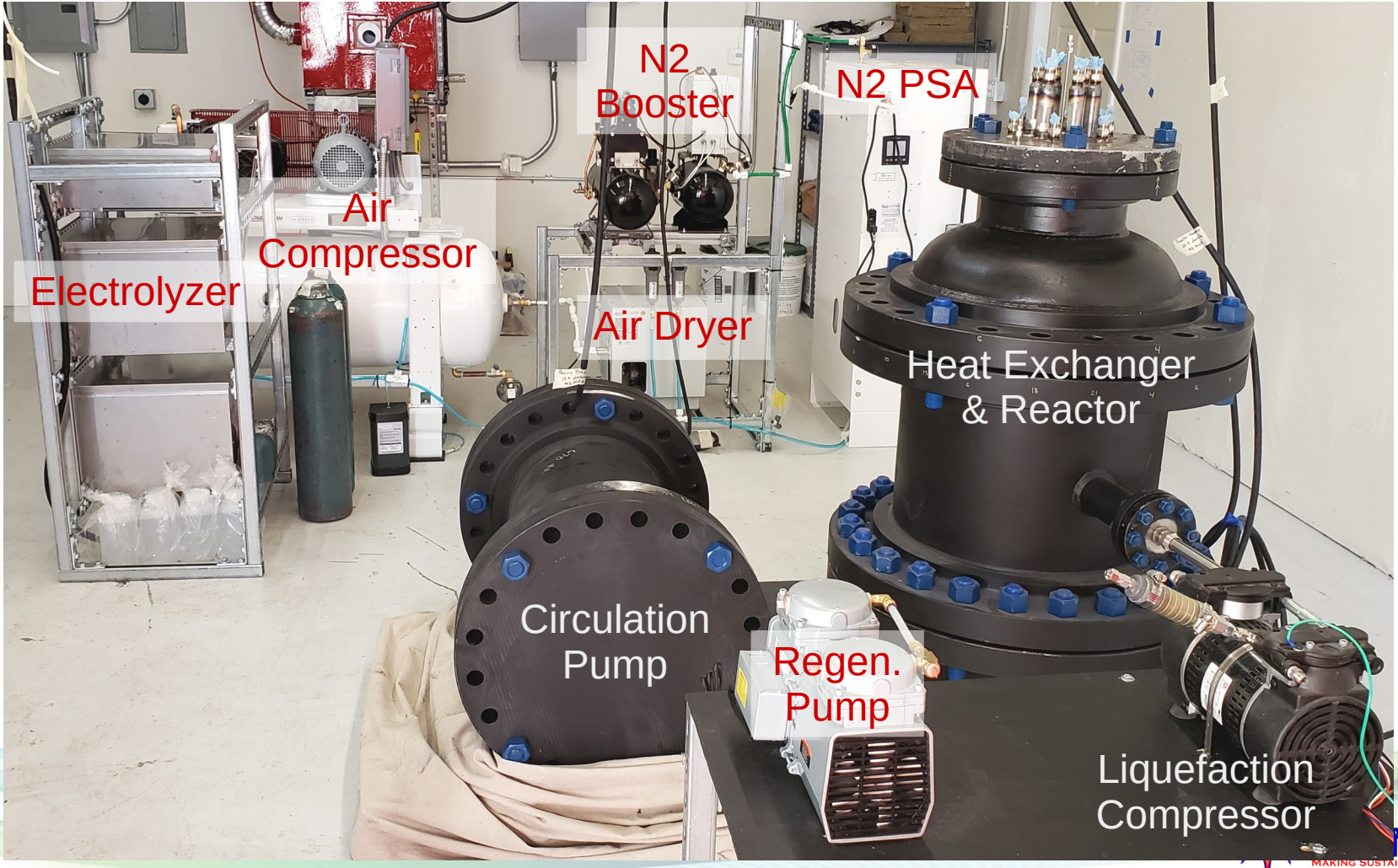
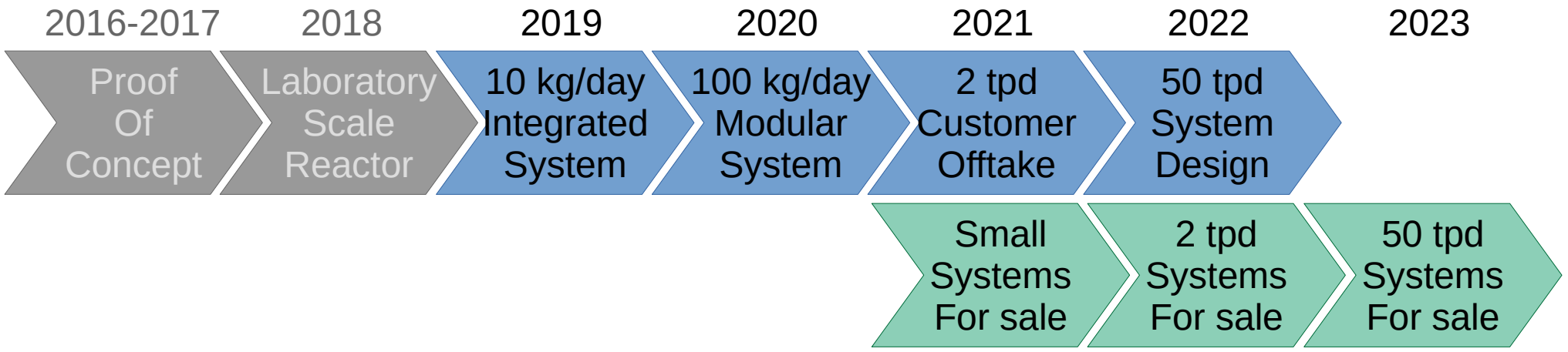
Building 10 kg/day system as we speak



10 kg/day is first of several iterations



- 10-25x scaling increments to 50 tpd
- Each scale has a purpose
- Integration, modularization, market validation, mass production

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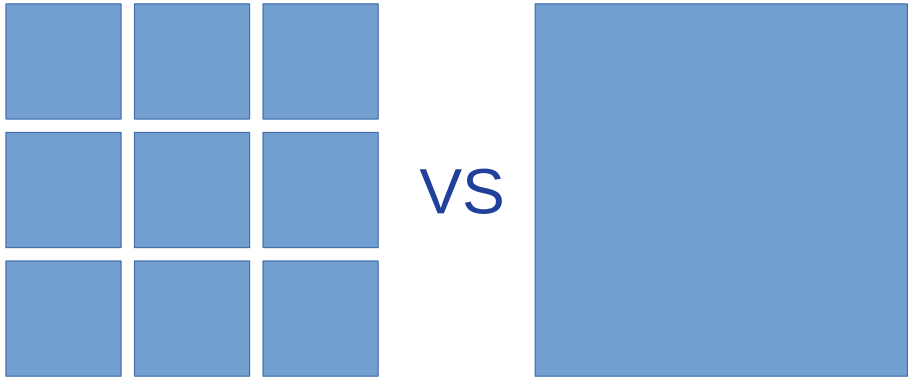
Modular systems reduce business risk

Two ways to increase capacity



Increase number of modular units

Increase unit size

- Cost $10M's instead of $1000M
- Add units as need increases
- Deploy near end-use
- Deploy near clean energy

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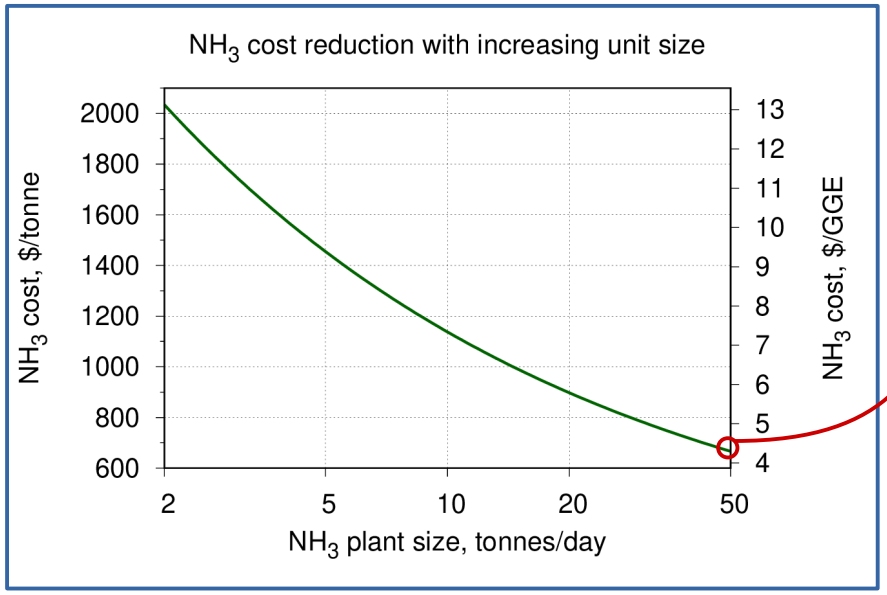
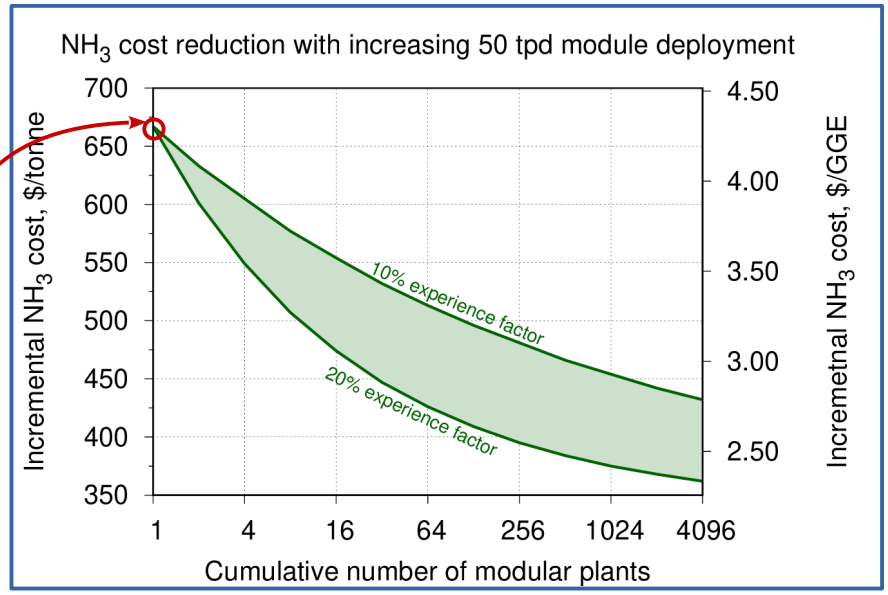
Unit size & mass prod. reduce NH_3 cost





- Assumes 65% CF, $0.01/kWh
- Unit size dictated by capex and desired initial NH_3 cost
- Mass production continues to drive down cost

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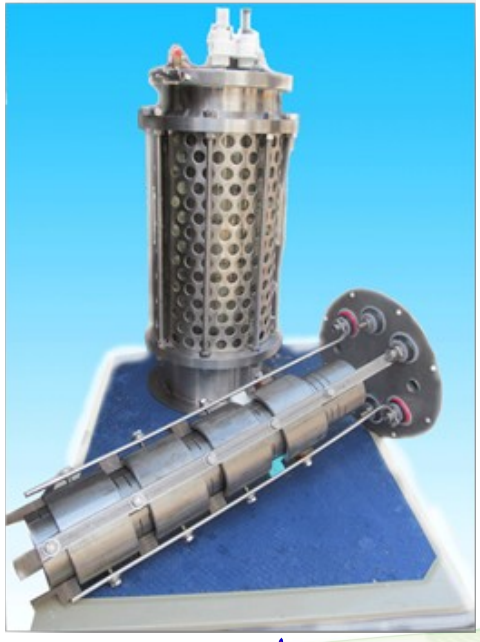
Synthesis tech refinement continues

SBIR·STTR
America's Seed Fund

HydroStar USA

- Lower capex membrane-less H_2
- Variable-power membrane N_2
- Better adsorbent material & process
- Capex – operating pressure – NH_3 cost



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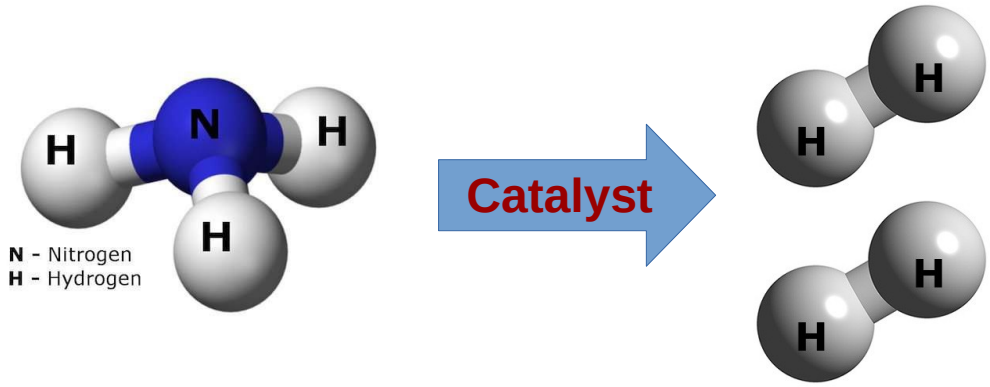
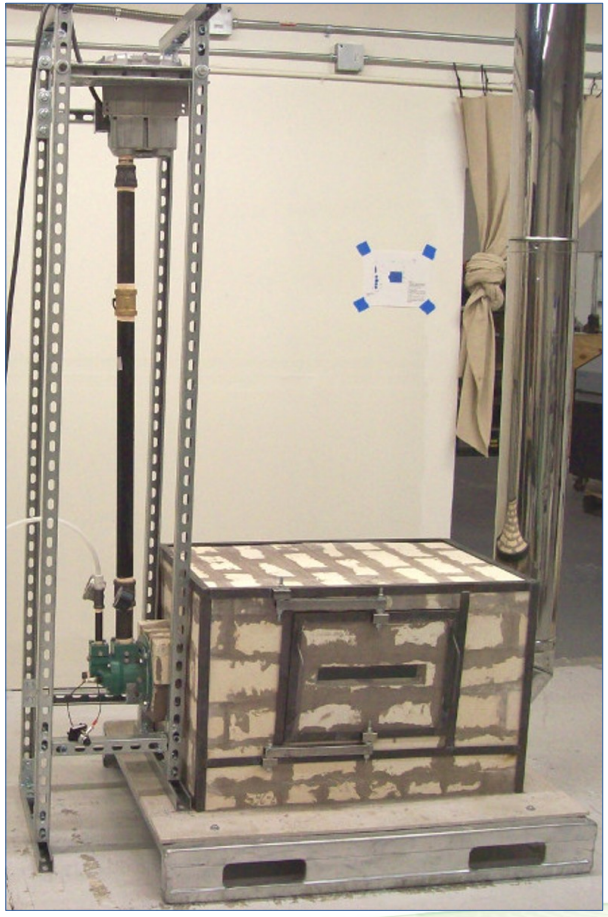
Expanding into NH_3 fuel utilization





- Monolith NH_3 cracking catalysts
- Natural gas burner conversion
- High purity, high pressure H_2 from NH_3

Expanding Starfire Energy's NH_3 team

Year	Staff
2015	1
2016	2
2017	3
2018	4
2019	7 + 1 part-time

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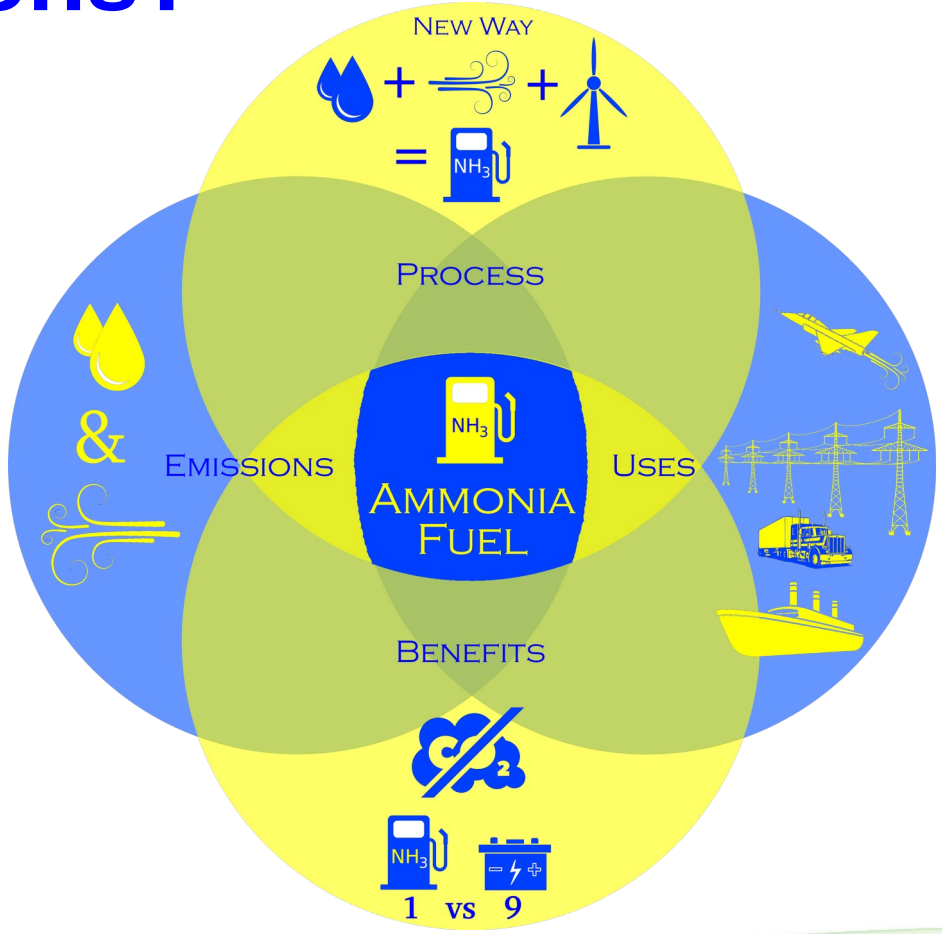
Questions?

- Monolith catalyst & NH_3 adsorption
- 10 kg/day system being built
- Iterate to 50 tpd modular system
- Mass produce to drive down costs
- Developing NH_3 fuel utilization tech



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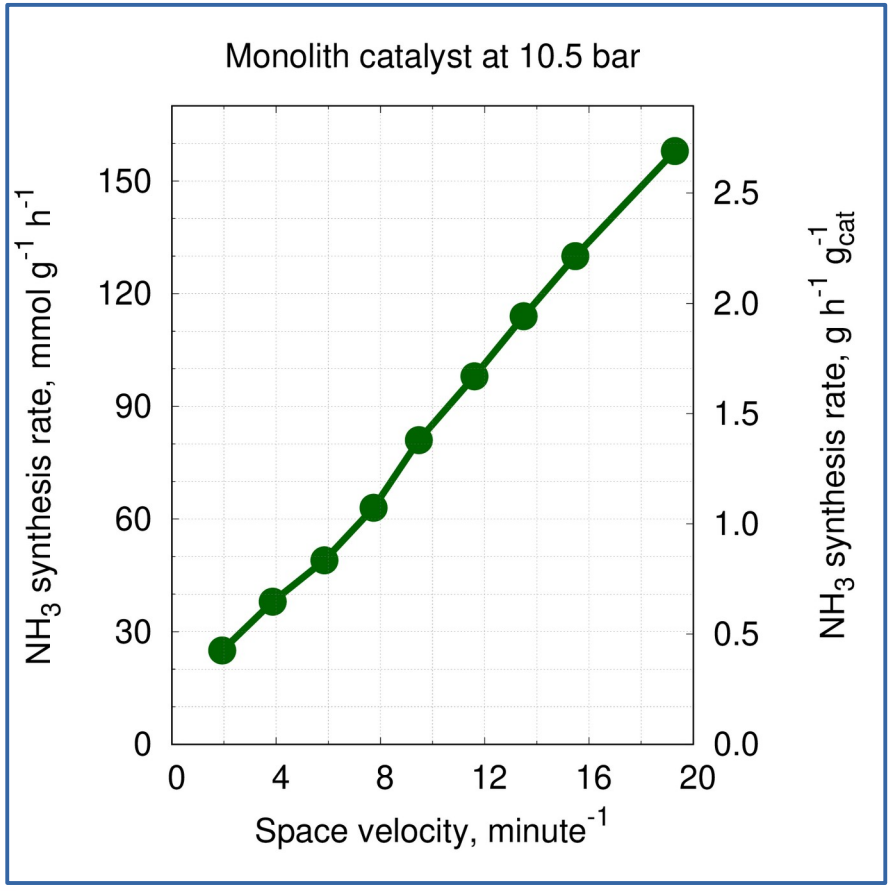
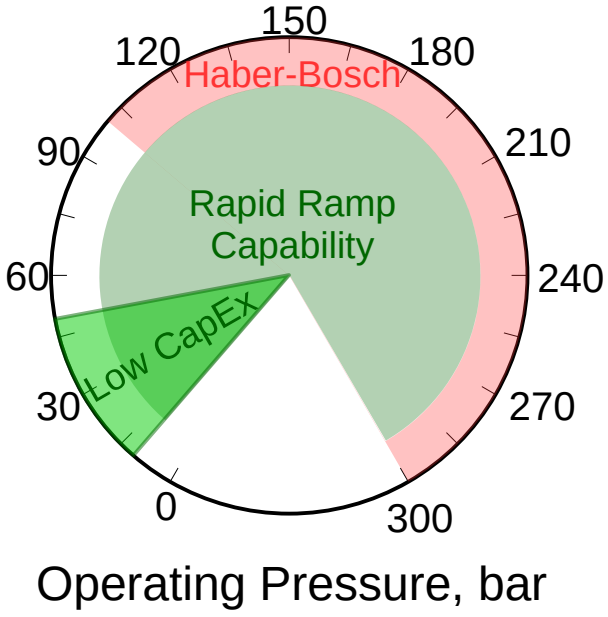
Additional slides

Synthesis rate ramps with reactant flow





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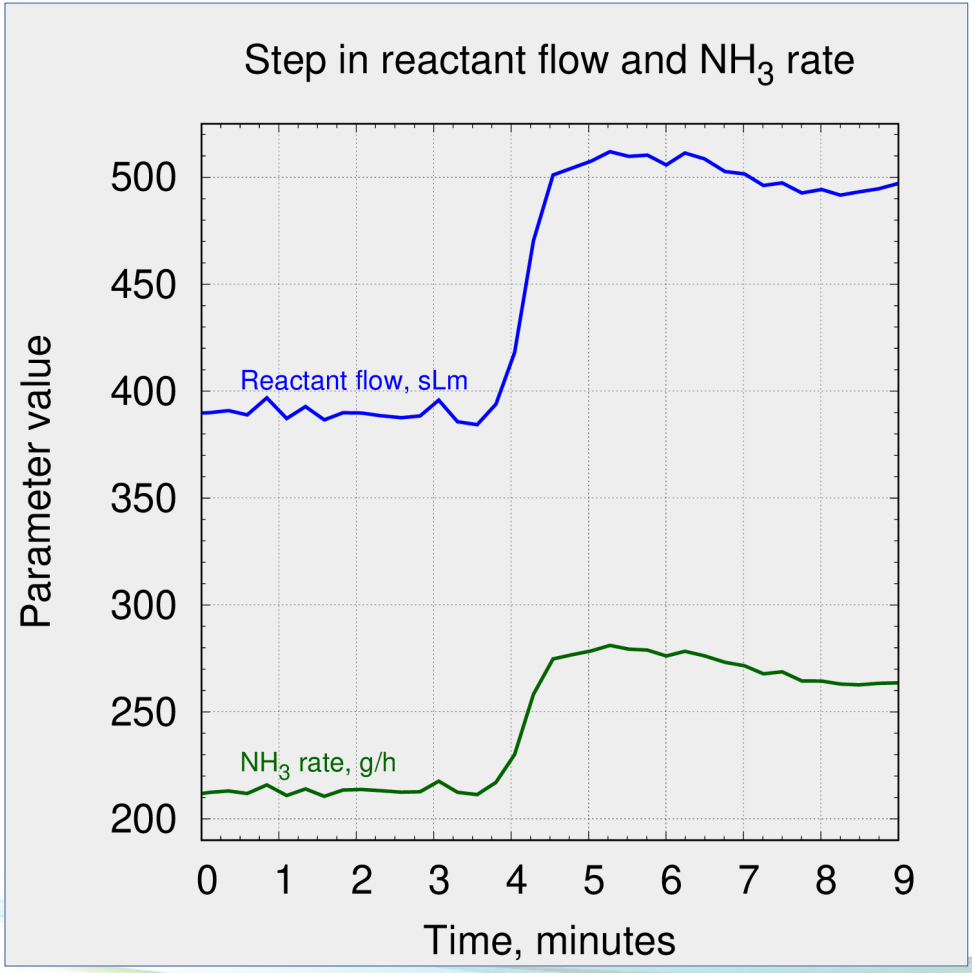
“Rapid Ramp” demonstrated



- 75% H_2, 25% N_2
- Flow increased by opening recirculator throttle valve
- Rate follows flow very closely
- Rate ramp rate = flow ramp rate

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