Advanced Heterogeneous Catalysts for Renewable Ammonia Synthesis

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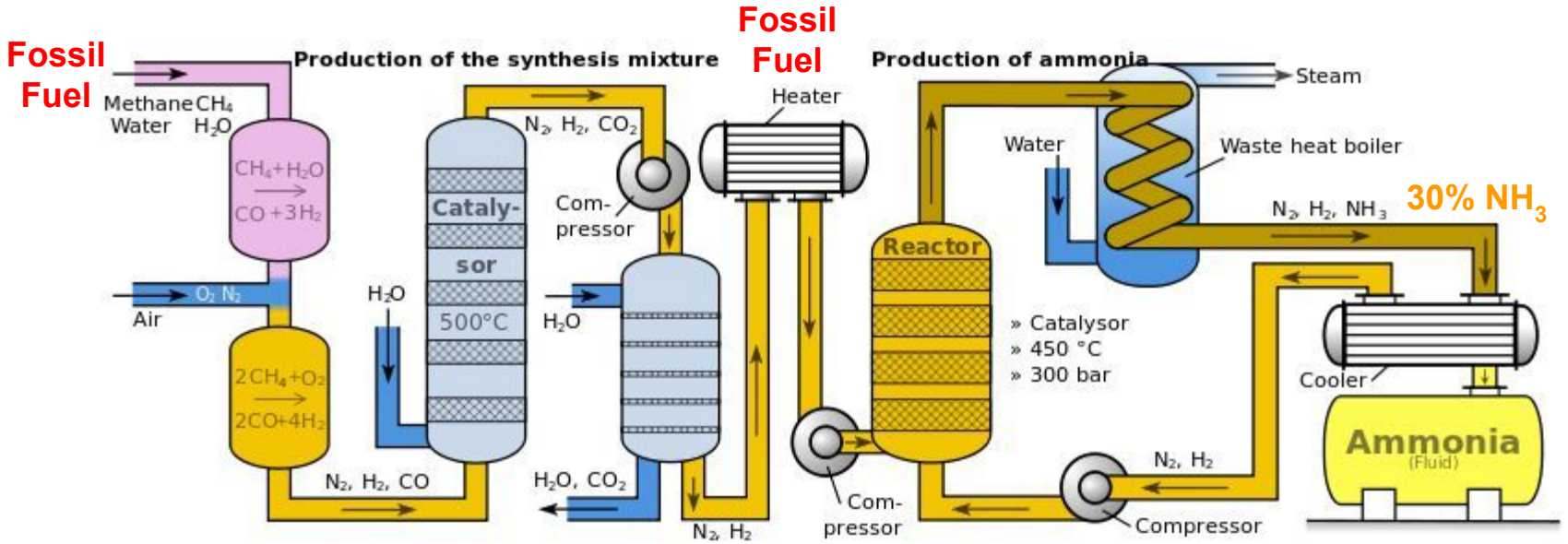
Traditional HB Synthesis of Fossil Ammonia

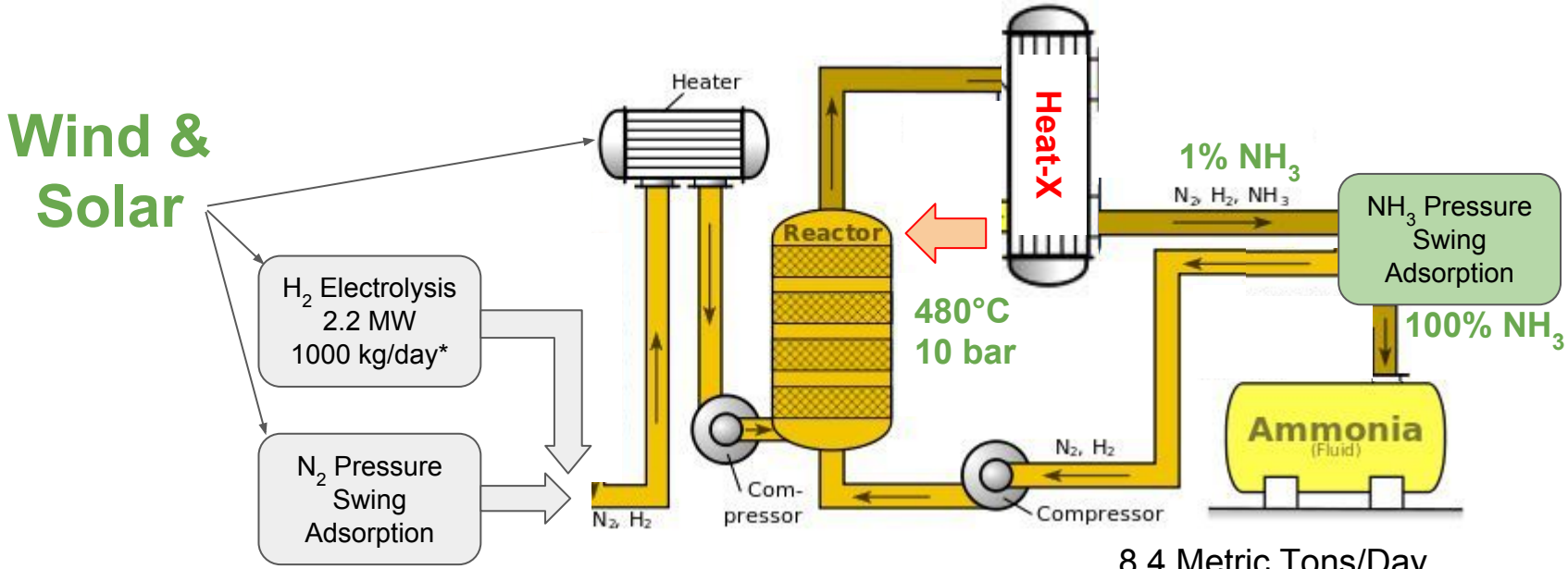


CO_2 Emissions

Typical Plant Size:
3000 Metric Tons/Day
1 Million Gallons/Day
0.6% Total World Production

Image source: https://phys.org/news/2011-11-closer-soluble-solution-haber-bocsh.html

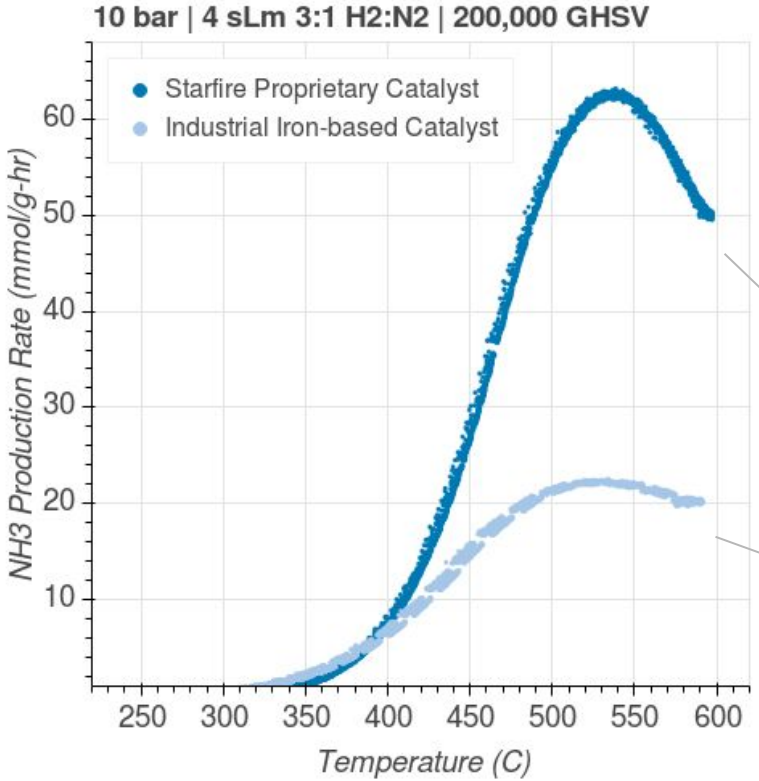
Smaller Scale HB Synthesis for *Clean* Ammonia

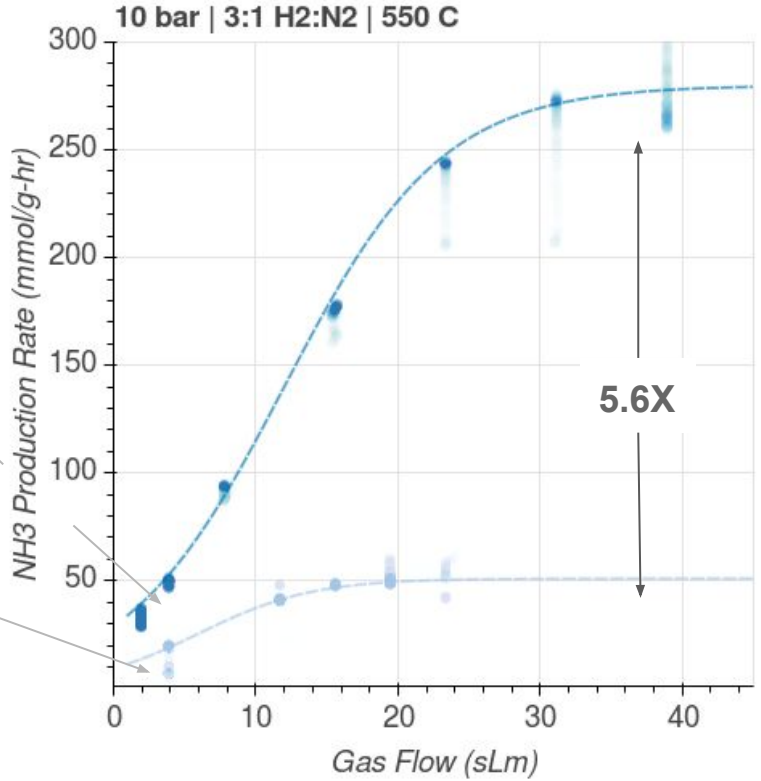


8.4 Metric Tons/Day
3000 Gallons/Day
0.002% Total World Production
size of typical gasoline filling station

*Nel *Series A,* alkaline electrolyser

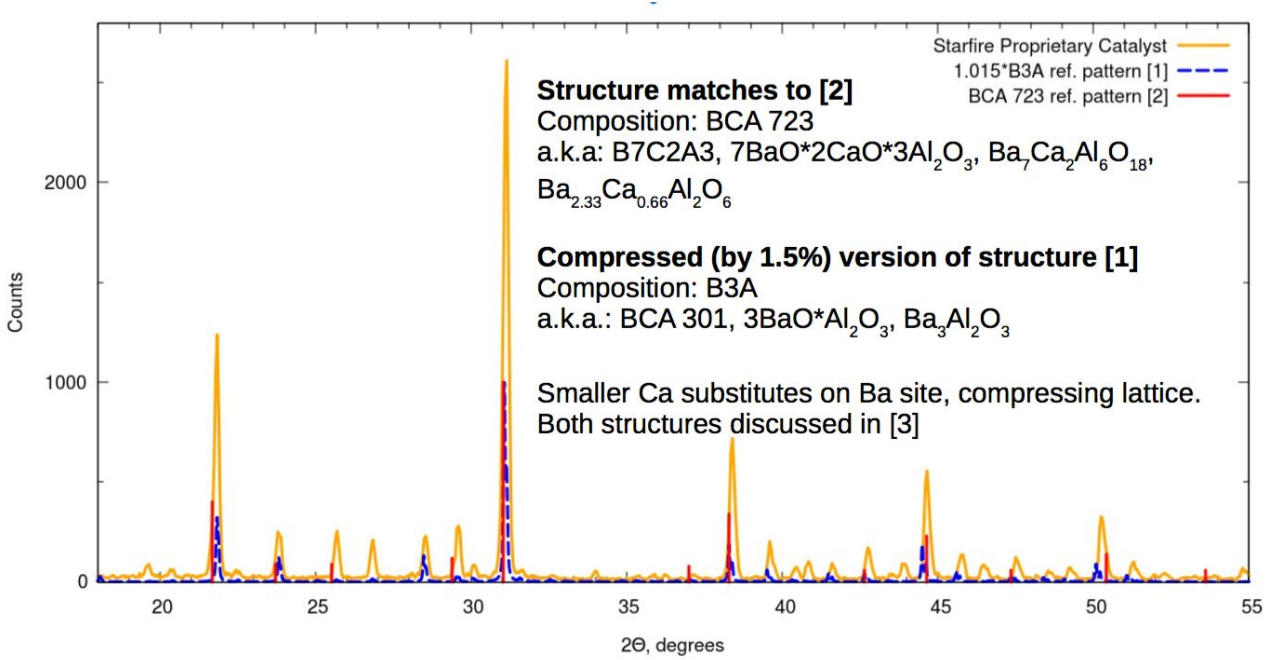
5.6X More Active Catalyst at Higher Flow Rates





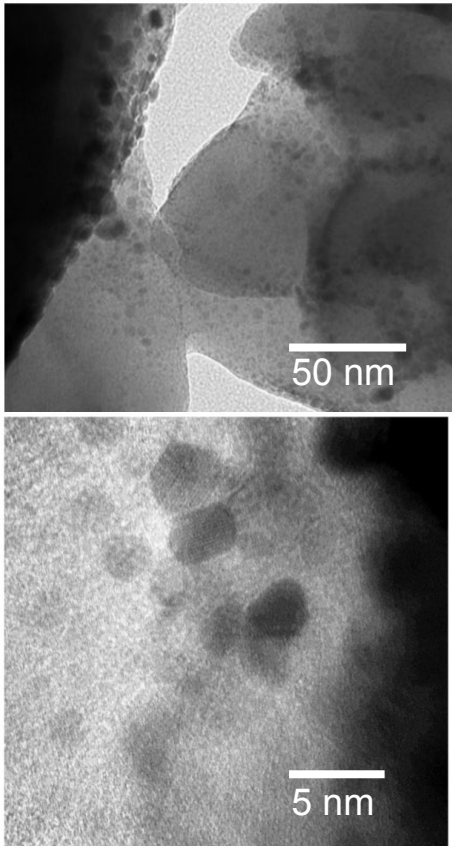
patents pending on the metal-decorated barium calcium aluminum oxide NH3 catalyst

Ru clusters on $Ba_7Ca_2Al_6O_{18}$



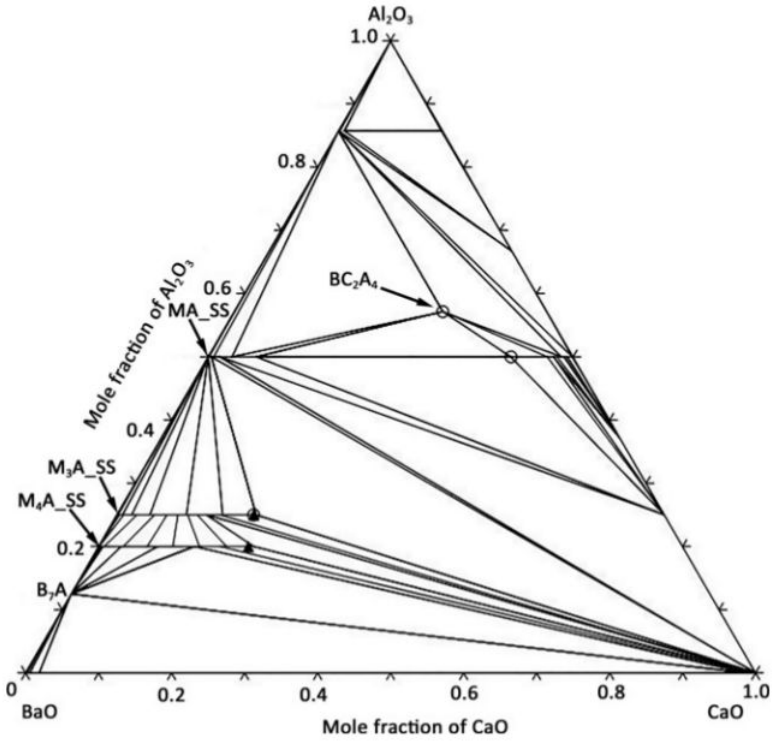
[1] B. Lazic, V. Kahlenberg, R. Kaindl, A. Kremenović. *Solid State Sciences* 11, p.77-84,(2009)
[2] Maklakov, A. A., E. P. Ostapchenko, *Zhurnal Strukturnoi Khimii*, Vol. 1, No. 2,p. 178-182, (1960)
[3] Walz, Leonhard, Martina Heinau, Birgit Nick, Jan Curda. *Journal of Alloys and Compounds* 216 (1994) p.105-112

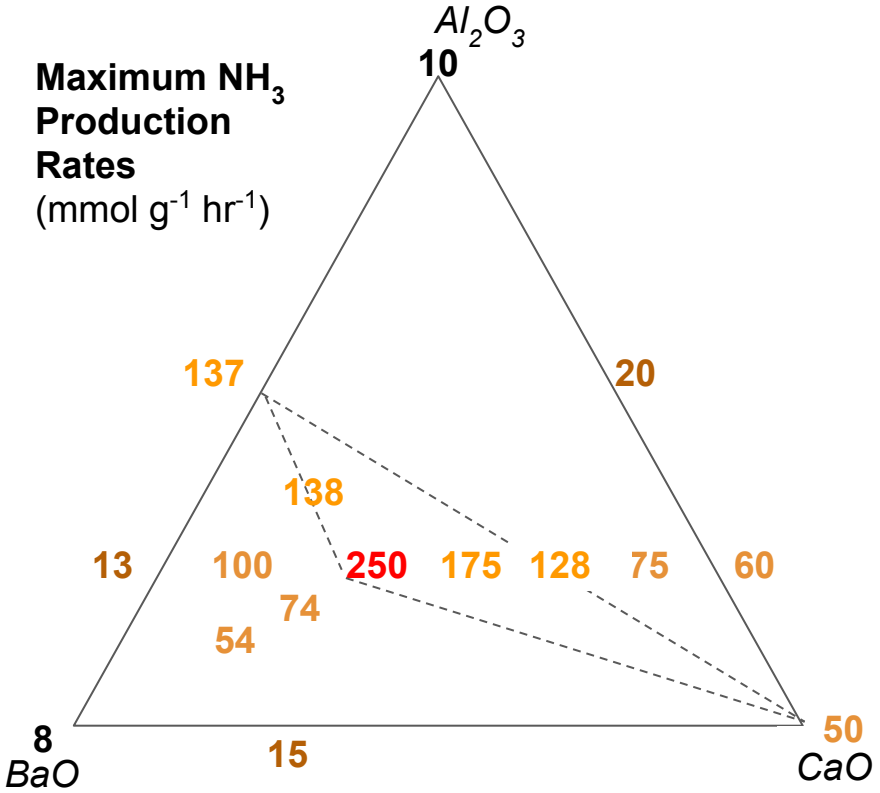
HRTEM, Transmission



Surface Area: 3.21 m^2/g
Ru Dispersion: 16.1%

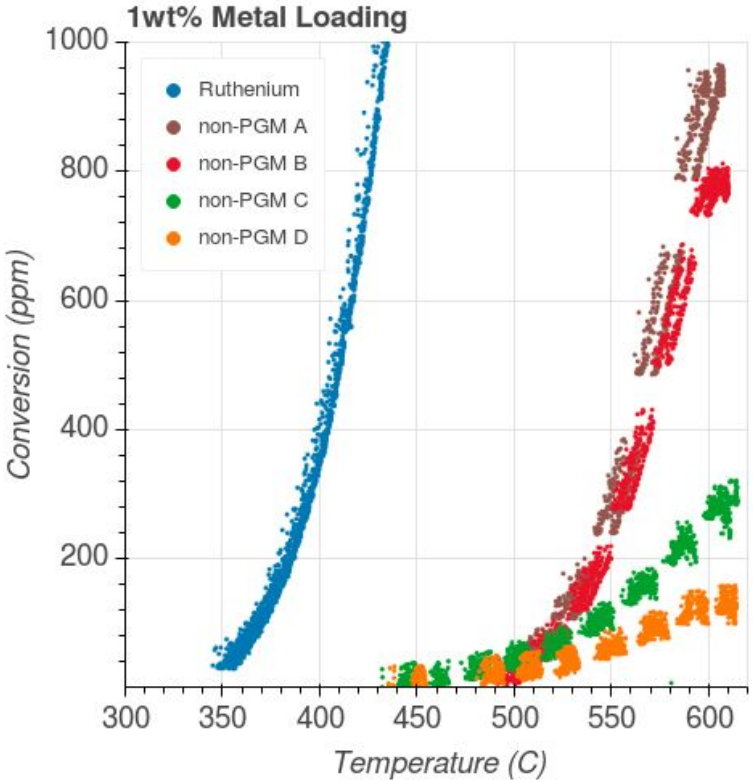
Optimizing Oxide Support

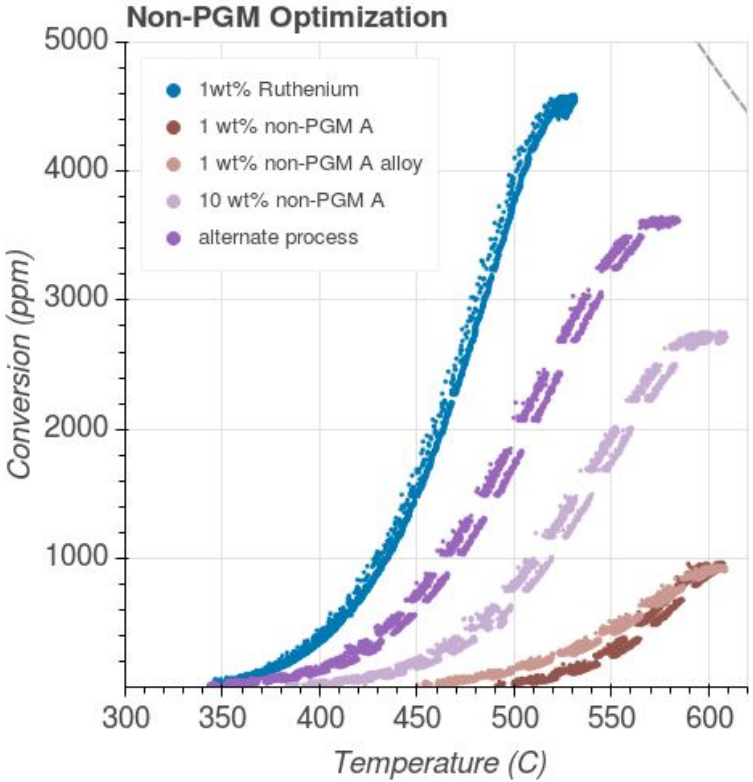




Zhang et. al., Jour. Am. Cer. Soc., April 2017.

Performance approaching Ru with non-PGM alternatives





Conclusions/Acknowledgments

OPEN 2015
Award #DE-AR0000685

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Christopher Cadigan PhD, Metallurgical and Materials Engineering
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