Green Hydrogen and Ammonia

Greg Butler 0427 424 278

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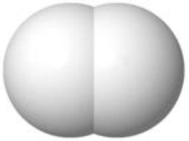
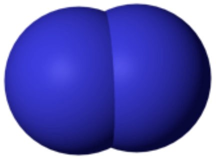


Hydrogen (H_2)

… is the **commercial limiting factor** for making **N fertiliser.**

… is a **clean energy carrier (fuel).**



Nitrogen (N_2) is readily filtered from the air.

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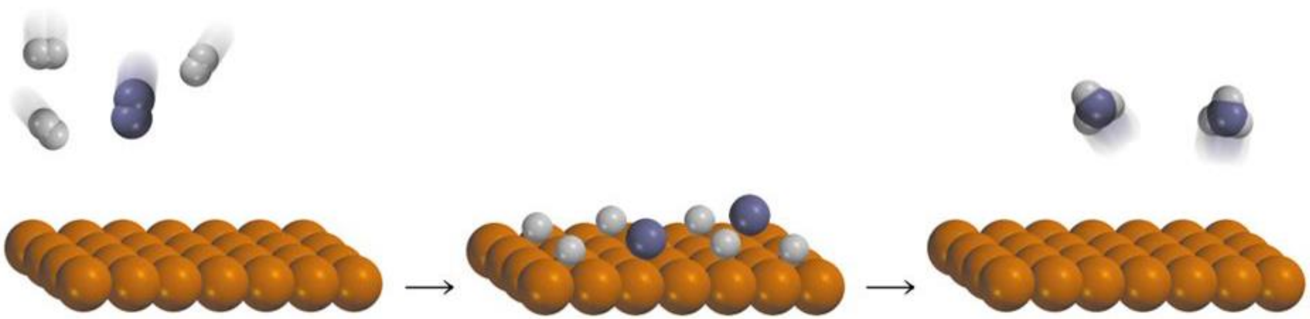
Hydrogen + Nitrogen = Anhydrous Ammonia



$$N_2\,(g) + 3H_2\,(g) \xrightarrow[\text{catalyst}]{Fe/Al_2O_3/K_2O} 2NH_3\,(g)$$

Ammonia synthesis invented over 100 years ago (Haber-Bosch).

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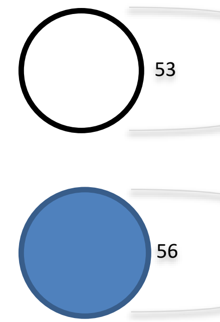
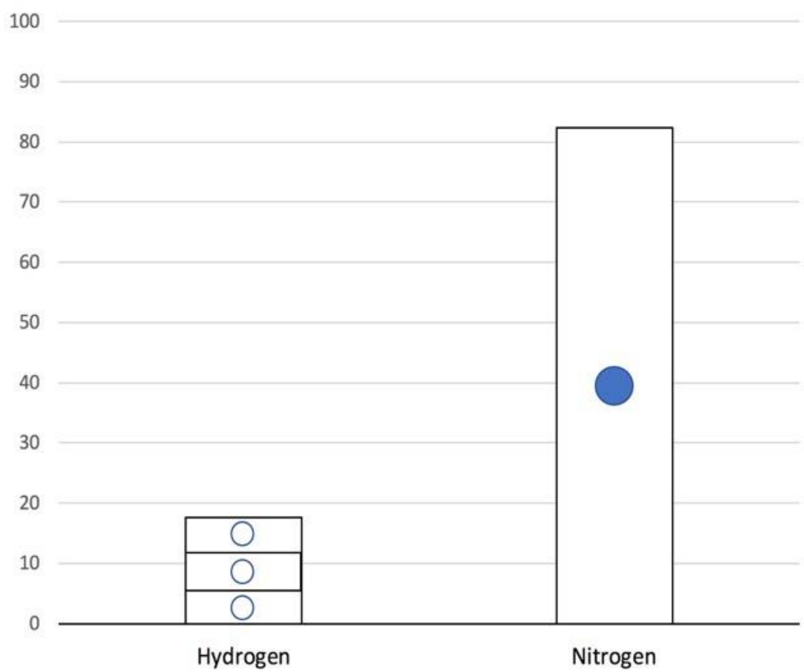
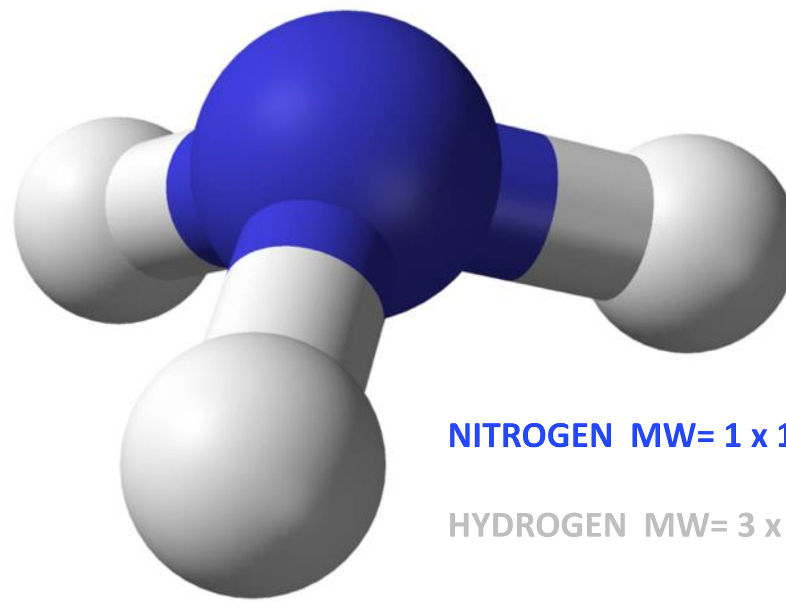
Ammonia's composition



18% Hydrogen.
82% Nitrogen.





NITROGEN MW= 1 x 14

HYDROGEN MW= 3 x 1

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How to make Hydrogen (H_2)

Fossil fuel:

Steam Methane Reforming

Coal Gasification

Renewable:

Electrolysis

Biomass

[Direct Ammonia]

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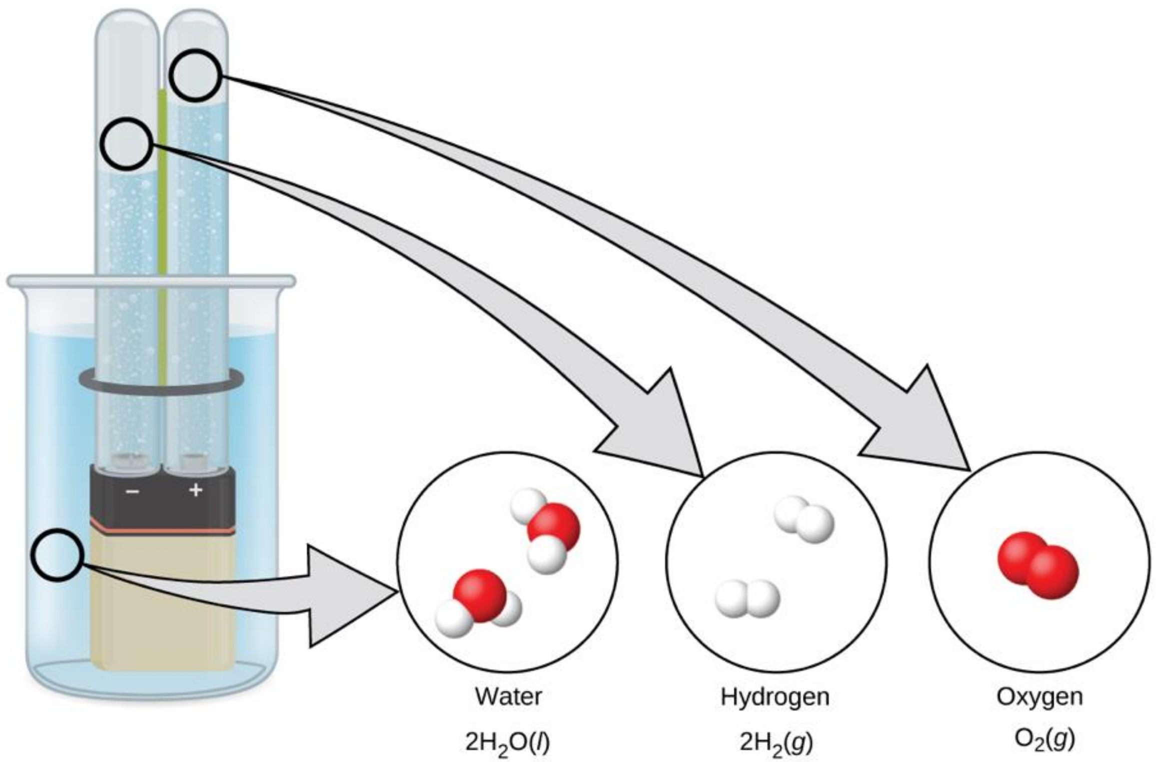
Electrolysis:

Water (H_2O) can be split into Hydrogen (H_2) and Oxygen (O_2) using Electricity.



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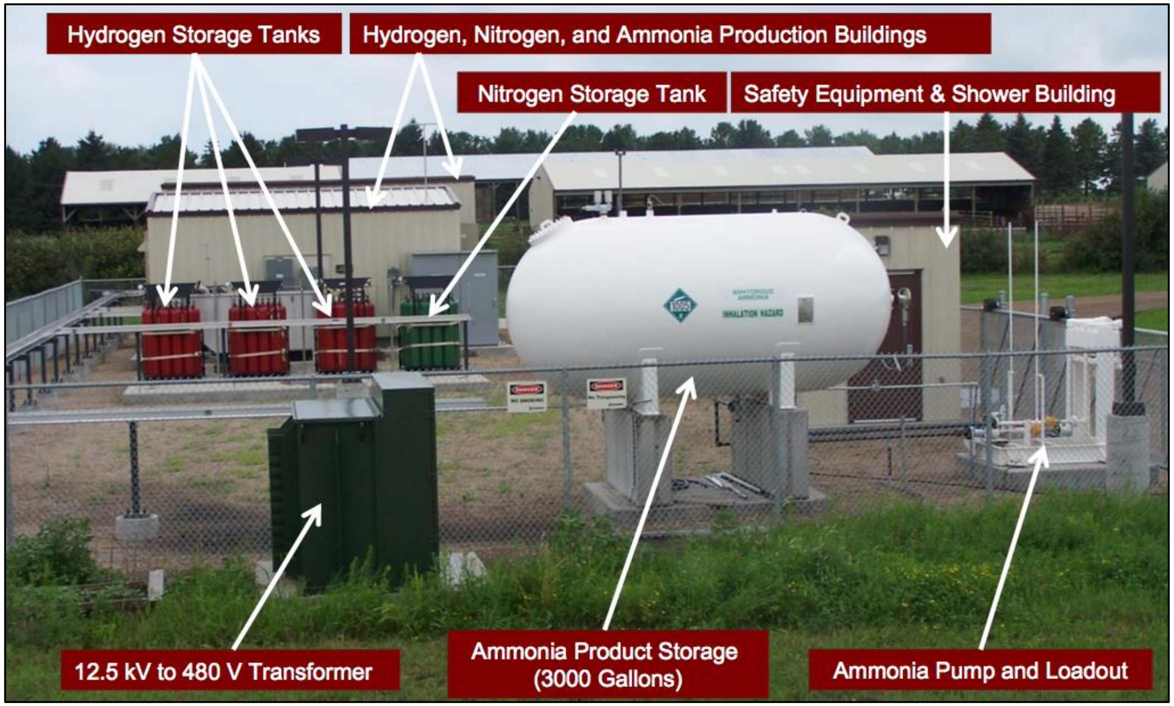
Farm scale proof of concept exists



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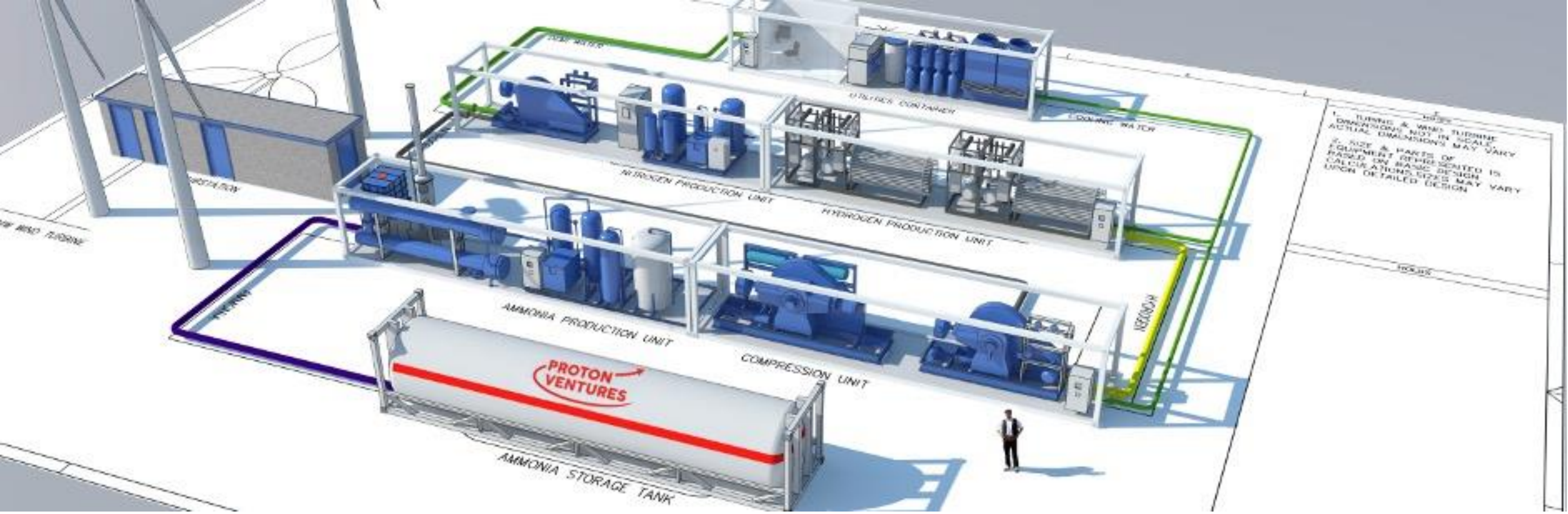

Electricity Req. (MW / hr)	Ammonia TPA N = 82%	Urea TPA N = 42%
1.5	1,000	1,952
6	4,000	7,809
30	20,000	39,047

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Reputable commercial solutions being developed.

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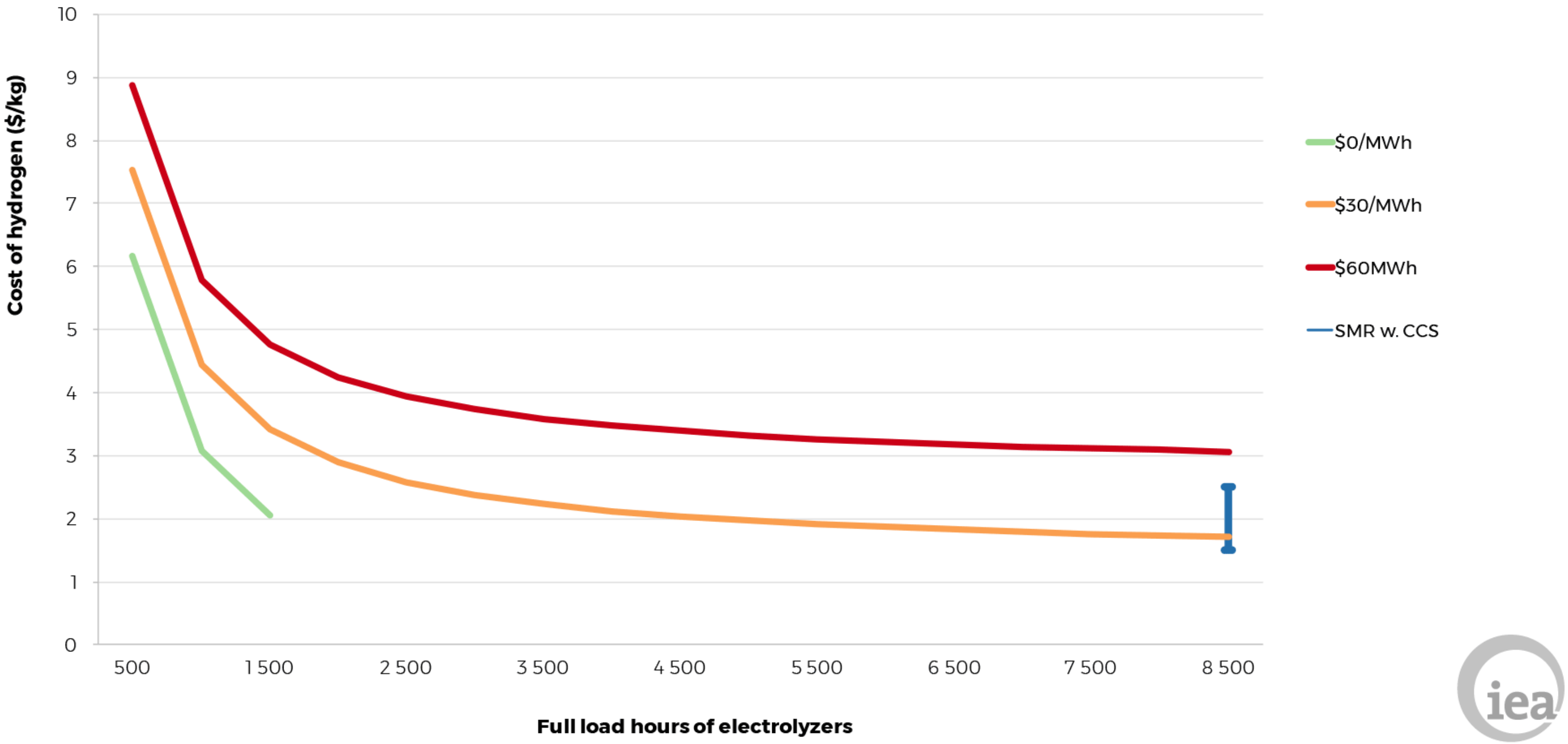
Costs of hydrogen as a function of utilization factor of alkaline electrolyzers for various electricity prices



Cost of raw H for 1T Anhydrous Ammonia

$1 = $179, $2 = $358, $3 = $536 $4 = 716

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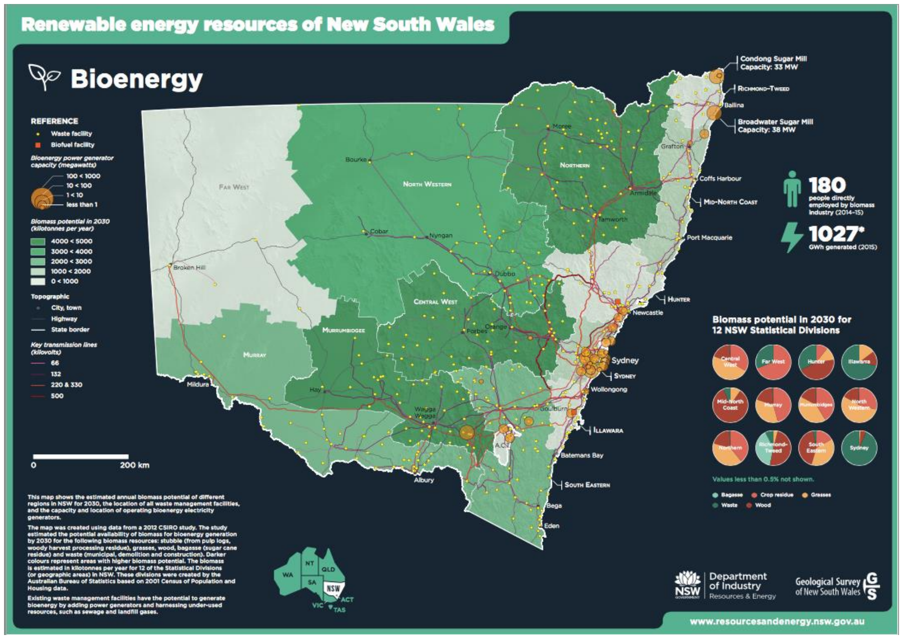
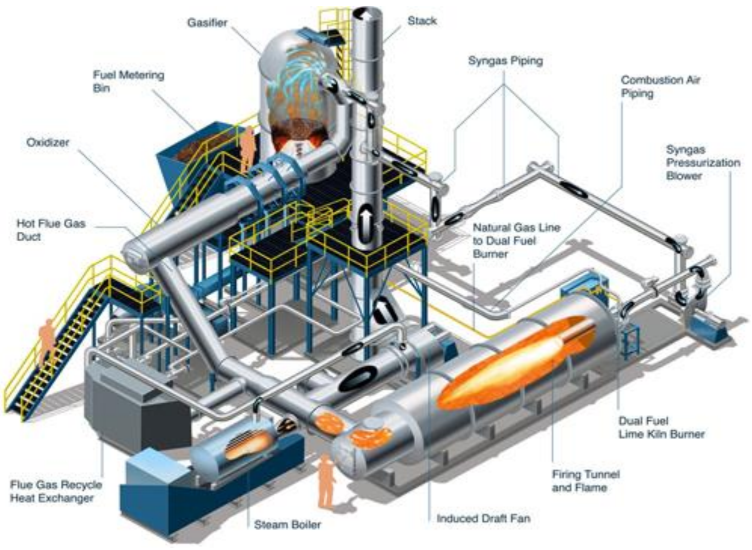
Hydrogen from Biomass





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Biomass Gasification for Hydrogen

Hydrogen yield of 6.5% from the gasification of wheat straw.

Then 100 kg of straw would produce 6.5 kg of hydrogen.

> 6.5 kg of hydrogen makes 36.8 kg of ammonia.

> 36.8kg of ammonia (82% N) converts into 71.8 kg of Urea (42% N).

> Biomass gasification could produce **718 kg of urea from 1T of wheat straw.**

Safari, F. et al. Hydrogen and syngas production from gasification of lignocellulosic biomass in supercritical water media.
International Journal of Recycling Organic Waste in Agriculture (2015) 4: 121. doi:10.1007/s40093-015-0091-5

In comparison, combusting wheat straw (1T) to make electricity (1MW) and then using electrolysis would produce enough Hydrogen for 149 kg of urea (-4.8X).

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Direct Ammonia Synthesis

New chemistry that does **NOT** use Hydrogen or Haber–Bosch for Ammonia.

Electrochemical synthesis of ammonia directly from N_2 and water over iron-based catalysts supported on activated carbon.

Baochen Cui,a,b Jianhua Zhang,a,b Shuzhi Liu, Xianjun Liu, Wei Xiang, Longfei Liu, Hongyu Xin, Matthew J. Leflerc and Stuart Licht
The Royal Society of Chemistry, Green Chem., 2017, 19, 298–304

Selective N_2 conversion to Ammonia using Water and Visible Light through plasmon-induced charge separation.

Tomoya Oshikiri, Kosei Ueno, and Hiroaki Misawa
Angew. Chem., 2016, Vol 128, Pg 4010 –4014.

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Hydrogen from Electrolysis

- Technology is available.
- Requires ample electricity (starting around 10MWh).
- Electricity can be from any source and can tolerate some supply variability.
- Siemens tolerance of 3MWh - 12MWh for nominal 10MWh system.

Hydrogen from Biomass

- Lab scale, still under development.
- Potentially higher efficiency.
- Requires sustainable biomass supply.

Direct Ammonia

- New chemistry, lab scale, still under development.
- Requires electricity / light / chemical engineering.

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- Higher regional production costs relative to massive scale of fossil fuel SMR plants.

+ Freight & supply chain advantage.

+ Self sustainability, guarantee of supply.

+ Carbon footprint when renewables are used compared to fossil fuels.

+ Reduce N and Fuel imports and regionalise budgets into local communities.

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