The Opportunity
Nitrogen & Hydrogen to Ammonia

- The UN predicts the world's population will grow to 9.8 billion by 2050, and as a result, we will need to increase food production by 60%
- Nitrogen is critical to plant growth, and therefore to the nutrition of people and animals
- However, plants are unable to take in the nitrogen that comprises 78% of the air (N$_2$)
- This N$_2$ needs to be converted into a form that plants can use
- So, we make ammonia (NH$_3$) as the first step to the fertilisers that plants can use to take in nitrogen
- To make ammonia (NH$_3$), nitrogen from the air (N$_2$) is combined with hydrogen (H$_2$)

\[ \text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3 \]
Hydrogen from natural gas

- To get the hydrogen we need, we use a process called steam-methane reforming.
- Natural gas, or methane (CH₄) is combined with oxygen (O₂).
- This reaction produces carbon dioxide (CO₂) and hydrogen (H₂).
- The world currently produces around 180 million tonnes of ammonia a year, with 95% of that produced via this process.
Hydrogen from water

- An alternative process to generate hydrogen harnesses electricity to split water (H$_2$O) into its constituents.
- To make ‘green’ hydrogen, this electricity must be generated from a renewable source such as the sun or the wind.
- However, these renewable sources are intermittent, whereas an industrial ammonia facility runs 24/7, 365 days of the year.
- Our challenge is to develop a system that allows intermittent electricity to power a constantly operating facility.
- If we can find an economic way to do this, the opportunities for such ‘green’ hydrogen may go well beyond ammonia and fertilisers.

$2\text{H}_2\text{O} + \text{energy} \rightarrow \text{O}_2 + 2\text{H}_2$
Yara - the Crop Nutrition Company for the Future

220 million
people our products help to feed

20 million
The number of farmers we collaborate with

9,000
Fully branded retail outlets

9,000
The number of countries we operate in

870
Agronomists on the ground

870
The number of people we employ

No. 10
Yara has been ranked no. 10 among the 50 companies on FORTUNES’ prestigious Changing the World List

+60
The number of countries we operate in

+16000
The number of people we employ

1 Owned and operated by external parties
2 Fortune List rating dates back to 2017
Our Ambition: towards climate neutrality

Past 15 years
Yara’s total greenhouse gas emissions halved by almost eliminating N₂O

Present
Improving on world leading performance: 10 % reduction ton CO₂/ton N by 2025

Future
Ambition to become climate neutral by 2050
Decarbonize Yara – exploring climate neutral agriculture through innovative partnerships

<table>
<thead>
<tr>
<th>What</th>
<th>Value drivers</th>
<th>Example</th>
</tr>
</thead>
</table>
| • Reduce Yara’s direct GHG emissions  
• Produce zero-carbon nitrogen  
• Solutions to reduce in-field agricultural GHG emissions  
• Contribute to green energy carrier solutions and green food value chains | • Higher revenue (consumers increasingly value products and solutions with lower environmental footprint)  
• Create new business and value creation models  
• Lower variable cost (carbon cost per tonne) | “Green ammonia” in Australia |

**What?** Feasibility study with ENGIE to produce zero emission ammonia  
**How?** Design a green hydrogen plant integrated with Yara’s existing ammonia plant in Pilbara  
**Why?** Significant reduction in CO₂ emissions and lower future costs
Circular Economy and Decarbonize are part of the solution to reduce global GHG emissions

**Contribution to global GHG emissions**

- Fertilizer production (1.5 %)
- Fertilizer consumption (1.5 %)
- Manure (3 %)
- Land use change (12.5 %)
- Shipping (3 %)

**The solution**

- Carbon neutral production
- Circular economy
- Digital solutions
- Farmer practice
- Logistics and ammonia energy

Based Source: IPCC 2014 Climate change synthesis and AFOLU reports, FAOSTAT, IFA,
* Emissions only, no sinks such as afforestation considered
First steps are taken, in cooperation with full value chain

Yara and Lantmännen lead the way towards world’s first fossil free food chain

Yara and Lantmännen take a pioneering role in transforming the food system. A pilot project with the ambition to introduce the world’s first certified fossil free food chain.

Yara and Nel collaborate to reduce electrolyzer costs; announce green ammonia pilot in Norway by 2022

by Trevor Brown August 23, 2019

This week, two Norwegian companies, fertilizer producer Yara and electrolyzer manufacturer Nel, announced an agreement to test Nel’s “next generation” alkaline electrolyzer at an ammonia production site. The parties expect to begin operating a 5 MW prototype in 2022, feeding green hydrogen directly into Yara’s 500,000 ton per year ammonia plant at Porsgrunn.

Yara with IBM to transform farming

by Charles Brust May 3, 2019

Yara International (Yara) and IBM have agreed to build a digital farming platform, with the intention that this feeds (sic) into the IBM Food Trust blockchain initiative. The agreement envisages the provision of holistic digital services and instant agronomic advice and will combine world-class agronomy with cutting-edge technology.

Yara and ENGIE to test green hydrogen technology in fertilizer production
Green Transformation via Hydrogen & Ammonia to (Nitrate) Fertilizer

New value chain

Green NH3/Fertilizer
- Electrolysis
- Renewable energy + H2O → Hydrogen
- Haber-Bosch → Ammonia
- Nitric acid & nitrate fertilizer

Standard NH3/Fertilizer
- SMR
- Fossil fuel → Hydrogen
- Haber-Bosch → Ammonia
- Nitric acid → Nitrate Fertilizer, Urea* Fertilizer

Illustration: Yara International ASA, all rights reserved.

* To produce zero-carbon urea, green ammonia to be recombined with carbon-negative CO2
Back to the future: Yara Norway until 1991
155MW electrolysis based ‘green’ ammonia production


Picture: courtesy of Nel Hydrogen ASA
Pilbara (WA) a place for green H2/NH3..

- Abundant stranded renewable energy resources – allowing renewable based industry as hydrogen and ammonia
- Unoccupied vast land availability
- Renewable energy converted to hydrogen – the best hydrogen carrier is ammonia
- Yara Pilbara ammonia facility – convert green H2 to green NH3.
- Close to key import markets for carbon-free energy
- Local opportunities, Supportive Policy & Care for the Environment
Yara and ENGIE – The Pilbara Partnership on green hydrogen & ammonia

• Collaboration in expertise

• Hydrogen produced linked to existing Yara Pilbara plant - Haber Bosch ammonia synthesis

• Mixed with Nitrogen to produce green ammonia for export

• Potential ~$200 million demonstration project

• Up to 100MW solar field / 66MW electrolysis plant

• Springboard for future projects, local and global
World leading export capabilities

- Yara Pilbara sells over 800,000 tonnes of ammonia, the building block for low-carbon fertilizer, per year

- Average 33 shipments per year from nearby Dampier Port

- Leveraging on the world leading Yara position in ammonia trading and naval logistics
Ready to connect: Green H2 for Ammonia synthesis

• Tie-ins installed, so that we are ready at any time to introduce the green hydrogen into our existing facility
Potential ramp up of green ammonia production in Pilbara

**PHASE 0**
Solar Add-on
- Conventional SMR
- Ammonia Syn. (HB) Plant
- Renewable Hydrogen Plant
- Demonstrate operationality of PV powered H2-Ammonia
  - 2022 / 30ktpa*

**PHASE 1**
Solar Expansion
- Conventional SMR
- Ammonia Syn. (HB) Plant
- Renewable Hydrogen Plant
- Green H2 scale-up
  - 2025-2030 / 180ktpa*

**PHASE 2**
Solar+Ammonia Expansion
- Conventional SMR
- Ammonia Syn. (HB) Plant
- Renewable Hydrogen Plant
- Build green ammonia Plant + expand green H2
  - 2025-2030 / 540ktpa*

**PHASE 3**
Green Plant Ramp-up
- Conventional SMR
- Ammonia Syn. (HB) Plant
- Renewable Hydrogen Plant
- Ramp-up green ammonia & green H2
  - 2025-2030 / 720ktpa*

* Expected time to market / volumes of green ammonia
<table>
<thead>
<tr>
<th>Company</th>
<th>Project</th>
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<tbody>
<tr>
<td>Yara</td>
<td>30 ktpa renewable NH$_3$</td>
</tr>
<tr>
<td>ENGIE</td>
<td>↓ C emissions across value chain</td>
</tr>
<tr>
<td>RioTinto</td>
<td>➡️</td>
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<tr>
<td>Woodside</td>
<td>Green H$_2$ pilot project study</td>
</tr>
<tr>
<td>KOGAS</td>
<td>$20M CSIRO NH$_3$ to H$_2$ partnership</td>
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<tr>
<td>Fortescue</td>
<td>Chichester Hub 100% renewable</td>
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<tr>
<td>Chevron</td>
<td>One of world’s largest CCS projects</td>
</tr>
<tr>
<td>BHP</td>
<td>$400M to address climate change</td>
</tr>
<tr>
<td>PROJECT 412</td>
<td>&gt;15GW Solar/wind project</td>
</tr>
<tr>
<td></td>
<td>Project KTA autonomous transport</td>
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</tbody>
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The Pilbara’s strategic renewables position

![Map of Pilbara showing key locations such as Dampier, Port Hedland, Karratha, Marble Bar, Newman, and others. The map highlights the strategic position of the Pilbara region in terms of renewable energy projects.]

- The Pilbara is home to some of the world’s largest CCS projects.
- $400M has been allocated to address climate change.
- One of the world’s largest Solar/wind projects.
- 30 ktpa renewable NH$_3$ is being produced.
- Green H$_2$ pilot project study.
- $20M CSIRO NH$_3$ to H$_2$ partnership.
- Chichester Hub 100% renewable.
- Project KTA autonomous transport.

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**Map of Pilbara showing key locations such as Dampier, Port Hedland, Karratha, Marble Bar, Newman, and others. The map highlights the strategic position of the Pilbara region in terms of renewable energy projects.**
The future will be different...