AMMONIA ENERGY ASSOCIATION

Ammonia Energy Conference 2020

PANEL 1: Cracking Ammonia 17 Nov 2020, 1.00-2.30pm GMT

Moderator: Bill David (STFC / University of Oxford, UK)

Panel: Joe Beach (Starfire Energy)
Gennadi Finkelshtain (GenCell Energy)
Josh Makepeace (University of Birmingham, UK)
Michael Dolan (Fortescue)
Camel Makhloufi (Engie)

Outline: The back story
Panel introductions
Panel discussion
Q&A

AMMONIA ENERGY ASSOCIATION

Membership Conference 2020 Articles Papers About

CF Industries — carbon free by 2050

- CF's existing asset base provides brownfield expansion opportunities, placing CF years and billions of dollars of investment ahead of greenfield projects
  - CF green ammonia production advantages:
    - Hydrogen from electrolysis can be fed into existing ammonia synthesis unit, displacing hydrogen from steam methane reformer
    - Existing logistics infrastructure available to store and deliver green ammonia efficiently
    - Unparalleled technical expertise exists within CF network
    - ~25% of total system electricity usage already from renewable resources
  - CF blue ammonia production advantages:
    - Existing CO_2 header and collection systems
    - Several production sites near CO_2 pipelines
    - Numerous CO_2 sequestration projects under development near our sites
    - Government incentives in place with 45Q credits ($31/ton, increasing to $45/ton by 2026)

News

Saudi Aramco ships blue ammonia to Japan for zero-carbon power

28 September 2020 (Last Updated September 28th, 2020 17:28)

Saudi Aramco and the Institute of Energy Economics, Japan (IEEJ) have collaborated with SABIC to send the first shipment of blue ammonia from Saudi Arabia to Japan to be used for generating zero-carbon power.

ARTICLE

OCP's Green Ammonia pilot plant, and the African Institute for Solar Ammonia

By Trevor Brown on August 17, 2018

Last week, OCP Group announced plans to develop green hydrogen and green ammonia as sustainable raw materials for use in fertilizer production. This includes building pilot plants in both Germany, already under construction, and Morocco, yet to begin construction, as well as "the possible establishment of an African Institute for Solar Ammonia."

Japan + Add to myFT

Japan bets on ammonia as the fuel of the future

The pungent gas could offer the best way for the country to import renewable energy

AIR PRODUCTS

News Release

Air Products, ACWA Power and NEOM Sign Agreement for $5 Billion Production Facility in NEOM Powered by Renewable Energy for Production and Export of Green Hydrogen to Global Markets

The World's Largest Green Hydrogen Project Will Supply 650 Tons Per Day of Carbon-Free Hydrogen for Transportation Globally and Save the World Three Million Tons Per Year of CO_2

July 07, 2020 Lehigh Valley, Pa.

Air Products, in conjunction with ACWA Power and NEOM, announced the signing of an agreement for a $5 billion world-scale green hydrogen-based ammonia production facility powered by renewable energy. The project, which will be equally owned by the three partners, will be sited in NEOM, a new model for sustainable living located in the north west corner of the Kingdom of Saudi Arabia, and will produce green ammonia for export to global markets.

The joint venture project is the first partnership for NEOM with leading international and national partners in the renewable energy field and it will be a cornerstone for its strategy to become a major player in the global hydrogen market. It is based on proven, world-class technology and will include the innovative integration of over four gigawatts of renewable power from solar, wind and storage; production of 650 tons per day of hydrogen by electrolysis using thyssenkrupp technology; production of nitrogen by air separation using Air Products technology; and production of 1.2 million tons per year of green ammonia using Haldor Topsoe technology. The project is scheduled to be onstream in 2025.

Air Products will be the exclusive off-taker of the green ammonia and intends to transport it around the world to be dissociated to produce green hydrogen for the transportation market.

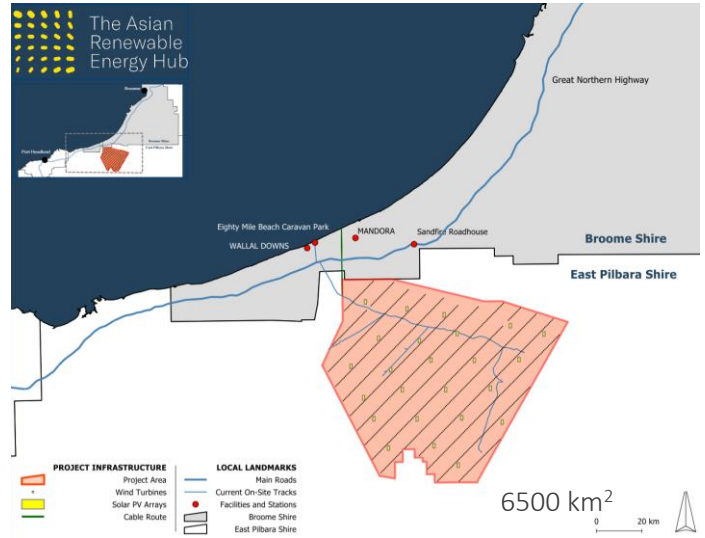
Ørsted and Yara Form Green Ammonia Pact

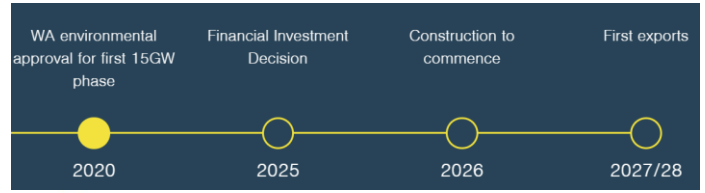
R&D

October 5, 2020, by Adnan Durakovic

Ørsted and Yara, the world's leading fertilizer company, have teamed up on a project to use renewable hydrogen in the production of green ammonia.

Yara and Ørsted will jointly develop a 100 MW wind-powered electrolyser plant for renewable hydrogen production, aiming to replace fossil-based hydrogen with green hydrogen for ammonia production in Yara's Sluiskil plant in the Dutch province of Zeeland.





RENEW ECONOMY

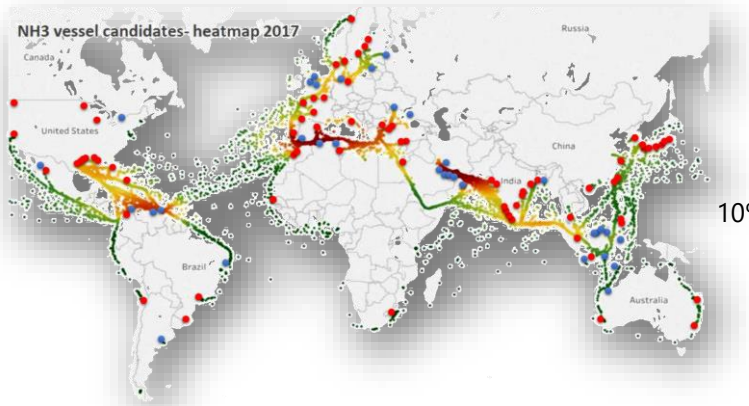
Clean Energy News and Analysis

SOLAR RENEWABLES STORAGE

Fortescue leads "stampede" into green energy with stunning plans for 235 gigawatts of wind and solar

Giles Parkinson 12 November 2020 0 Comments Share

https://www.ammoniaenergy.org/articles/green-ammonia-in-australia-spain-and-the-united-states/?mc_cid=bfaa66f828&mc_eid=54c16878c0
https://www.power-technology.com/news/saudi-aramco-ships-blue-ammonia-japan-zero-carbon-power-generation/
https://www.japantimes.co.jp/news/2020/09/28/business/corporate-business/saudi-arabia-blue-ammonia-japan/
https://www.ft.com/content/254e44c4-afec-11ea-94fc-9a676a727e5a
https://s1.q4cdn.com/264428898/files/doc_presentations/2020/10/29/CF-Commitment-to-Clean-Energy-Economy-presentation-Oct-29-2020.pdf
https://reneweconomy.com.au/fortescue-leads-stampede-into-green-energy-with-stunning-plans-for-235-gigawatts-of-wind-and-solar-27936/
https://asianrehub.com/



NH_3 NH_3:H_2

10% global: 18,000,000 tonnes NH_3/year
~ 3,000,000 tonnes H_2/year
~25,000,000 cars
(× 400)

HYDROGEN

PEM

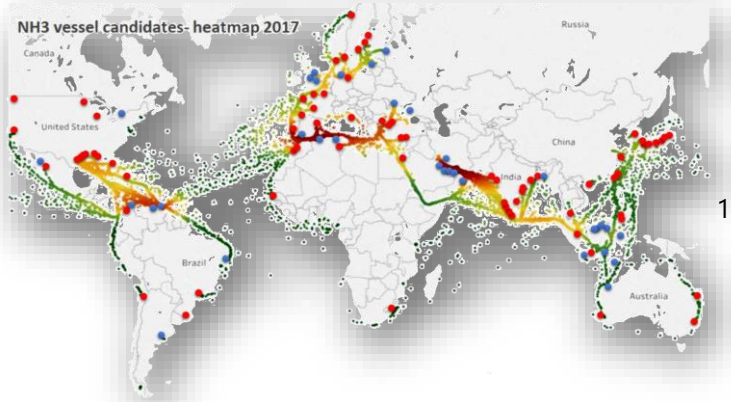
99.9999%

Global hydrogen refuelling infrastructure
100kg/day × 150 days × 500 stations
= 7,500 tonnes/year | 60,000 cars

First ammonia engines for commercial use are due out in 2024

New test engine debuts on Copenhagen's roads during lockdown

17 June 2020 9:35 GMT *UPDATED 17 June 2020 9:35 GMT*



NH_3 NH_3:H_2

10% global: 18,000,000 tonnes NH_3/year
~ 3,000,000 tonnes H_2/year
~25,000,000 cars
(× 400)

AMMONIA | HYDROGEN

AMMONIA

<5% 0 – 30% ~30%

SOFC **MARITIME** **ICE** **AVIATION**

retrofitted technologies
existing infrastructures

>99% AFC PEM

99.9999%

HYDROGEN

0% → CONVERSION →

British scientists lead 'clean skies' drive with ammonia-fuelled jets

10 Aug 2020

By Hannah Boland

TRAVELLERS may be able to enjoy guilt-free "green" holidays within years thanks to eco-friendly aeroplane technology being developed in Oxford.

Reaction Engines has begun work on systems which will turn existing commercial aircraft "emission-free", by allowing them to run on ammonia rather than kerosene.

Ammonia, which is different from ammonium nitrate, would be safer than traditional kerosene because it is harder to burn and so less of a fire hazard, the researchers said. When it does burn, it does so without CO2 emissions.

The way the system works is that ammonia could be fed in and split into hydrogen and nitrogen, with the former burned to fuel the jet.

James Barth, the engineer behind the project, said there were key benefits in using ammonia over pure hydrogen. It could be stored in a plane's wings, as kerosene is, and is cheaper.

This would mean commercial airlines would only have to adapt their existing fleet, rather than redesign models, and it would not mean higher air fares.

"There's no reason why we couldn't have a small-scale demonstrator ready to test in a matter of years," Barth said.

There has been a wave of trials of battery-powered planes, with companies such as Rolls-Royce, Airbus and Siemens looking into such projects.

But experts say the range of electric planes would be severely limited. Ammonia-fuelled planes would be able to handle most short-haul flights, although the range is still less than that of existing planes.

The project is taking place at the Harwell Campus in Oxford, funded by government agency the Science and Technology Facilities Council.

There has been a major push for the UK to cut carbon emissions, and last year the Government pledged to have net zero emissions by 2050.

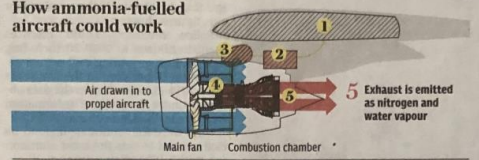
Mark Thomas, Reaction's chief executive, said the pandemic could help in the push towards green travel. "We've been living under clean skies for the past few months," he said.

"It is becoming clear there is going to be a real technology drive."

In France, bail-out funding for aerospace industries has been linked to emissions targets.

'We've been living under clean skies. It is becoming clear that there is going to be a real technology drive'

How ammonia-fuelled aircraft could work



1 Ammonia is pumped from the fuel tank to the jet engine

2 The ammonia is heated as it passes through heat exchangers

3 The ammonia then passes through a 'cracking reactor' where a catalyst splits it into hydrogen and nitrogen

4 Ammonia/hydrogen fuel blend is fed into the engine combustion chamber

Global hydrogen refuelling infrastructure
100kg/day × 150 days × 500 stations
= 7,500 tonnes/year | 60,000 cars

Reaction Engines, STFC engaged in ground-breaking study on ammonia fuel for a sustainable aviation propulsion system

Tue, 2020-08-18 12:38

Reaction Engines has recently completed a joint Proof of Concept study with the UK's Science and Technology Facilities Council (STFC) to determine whether the Company's innovative thermal management technology could be combined with STFC's world-class catalysts to create a truly green aviation system based on ammonia fuel.

In recent years, ammonia has been considered by various industries for use in power generation as it is carbon free, offers high energy density and has an established transportation network in contrast to hydrogen which has issues with both storage and distribution. Similarly, the maritime industry is looking to ammonia as a low-cost way to decarbonise shipping. Up until now however, it has not been proven to be viable as a fuel for aviation propulsion systems.

Decarbonizing the aviation industry is one of the great challenges of our age. Most modern aircraft are powered by kerosene, a jet-fuel which is a flammable hydrocarbon oil and produces carbon dioxide, sulphur oxides and soot. The emissions generated from this method of propulsion contribute a significant amount to the total global greenhouse gas production.

"Green ammonia storage and real-zero ammonia-hydrogen fuel mixtures have the potential, not only to enable carbon-free, and indeed guilt-free, aviation but also, in time, to completely remove our dependence on fossil fuels."

https://www.reactionengines.co.uk/news/news/reaction-engines-stfc-engaged-ground-breaking-study-ammonia-fuel-sustainable-aviation-propulsion-system