IRENA
International Renewable Energy Agency

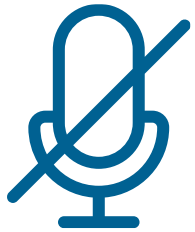
in partnership with

AMMONIA ENERGY ASSOCIATION

INNOVATION OUTLOOK

RENEWABLE AMMONIA

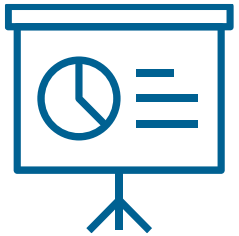
19 May 2022

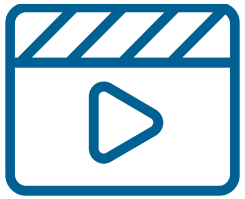


All microphones are **muted**

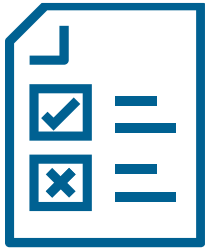
Use the **Chat** feature to introduce yourself and talk to other attendees

If you have **Questions** to the speaker please use the dedicated **Q&A** tab





The slides and recordings will be shared via email after the end of the webinar



Tell us how we did in the survey to help us improve

Welcome Remarks

Dolf Gielen

Director – Innovation and Technology Centre, IRENA

Trevor Brown

Executive Director – Ammonia Energy Association

Setting the scene presentation – The Role of Green Ammonia in the Energy Transition

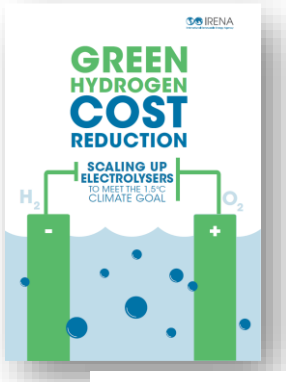
Dolf Gielen

Director – Innovation and Technology Centre, IRENA

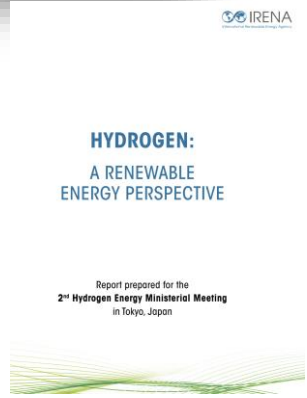
IRENA's comprehensive framework to scale up green hydrogen and its derivatives

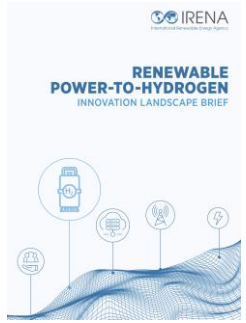
IRENA
International Renewable Energy Agency

Supply

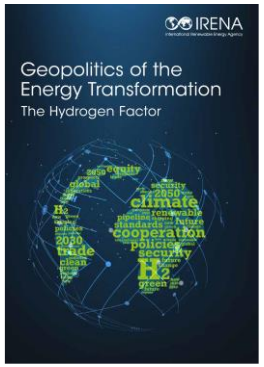


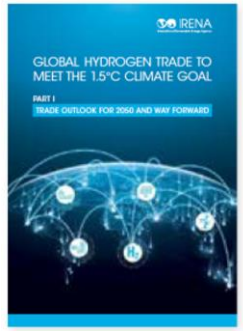
Sector coupling

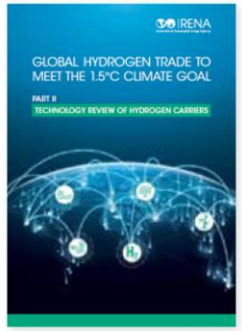


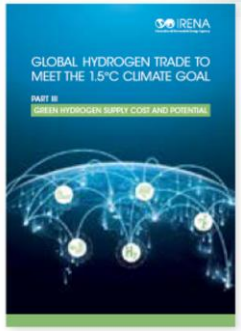


Trade

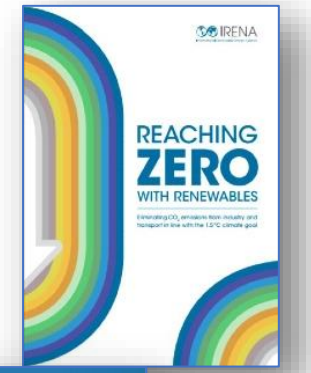


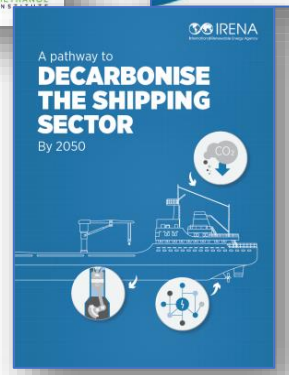




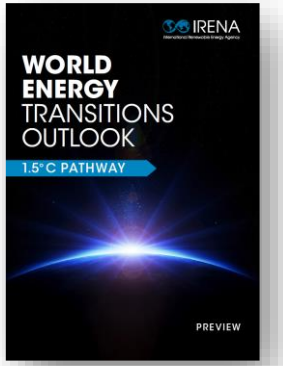


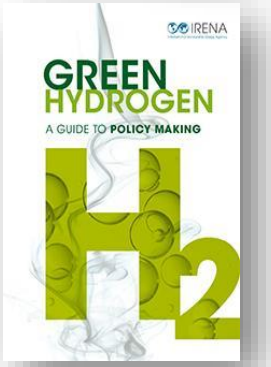
Demand





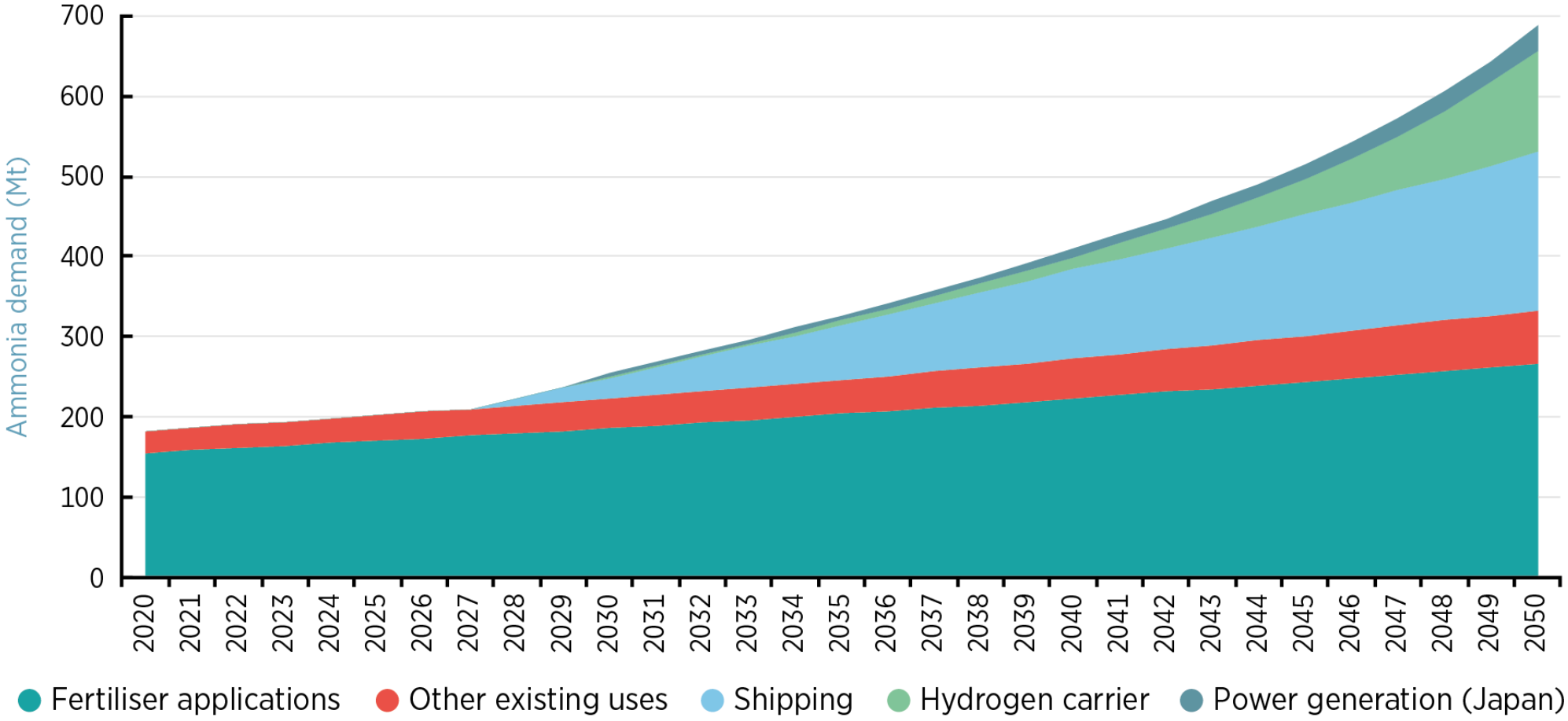
Cross cutting & Enabling Framework





Ammonia market status and prospects – demand side

Expected ammonia demand up to 2050 for the 1.5°C scenario

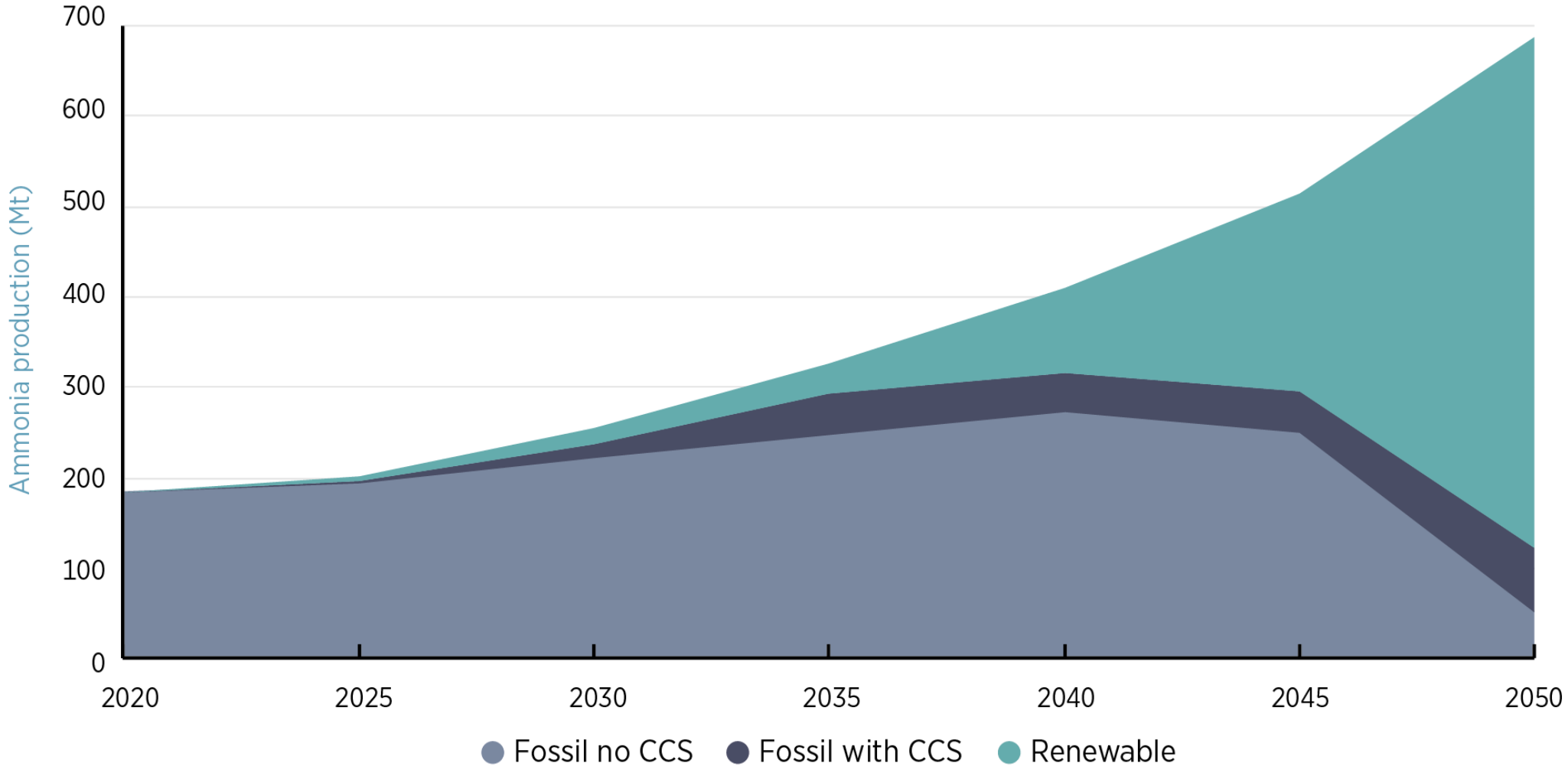


- Green ammonia to replace current ammonia demand
- Future possible green ammonia applications as shipping fuel, hydrogen carrier and power generation

For a Net-Zero future most ammonia must be renewable – supply side

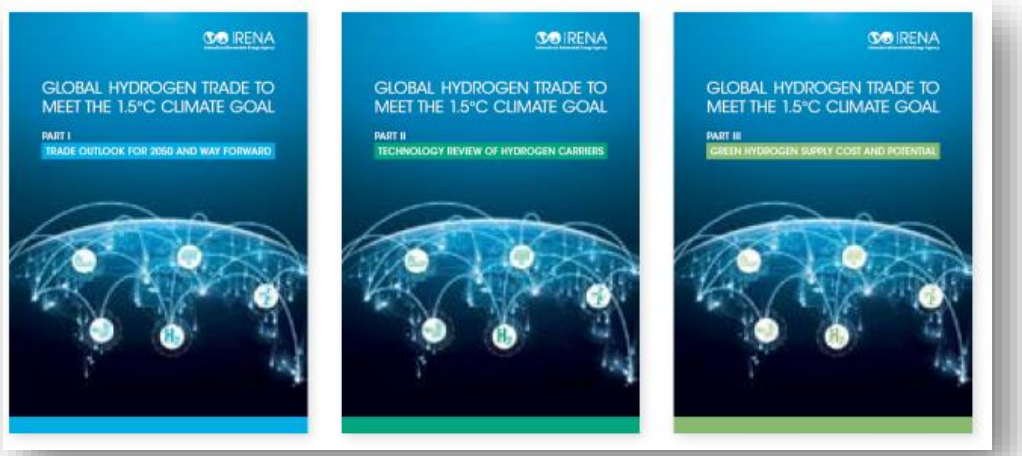
- Sector coupling requires attention
- Implications on additional renewable electricity generation capacity

Expected ammonia production capacity up to 2050 for the 1.5°C scenario.

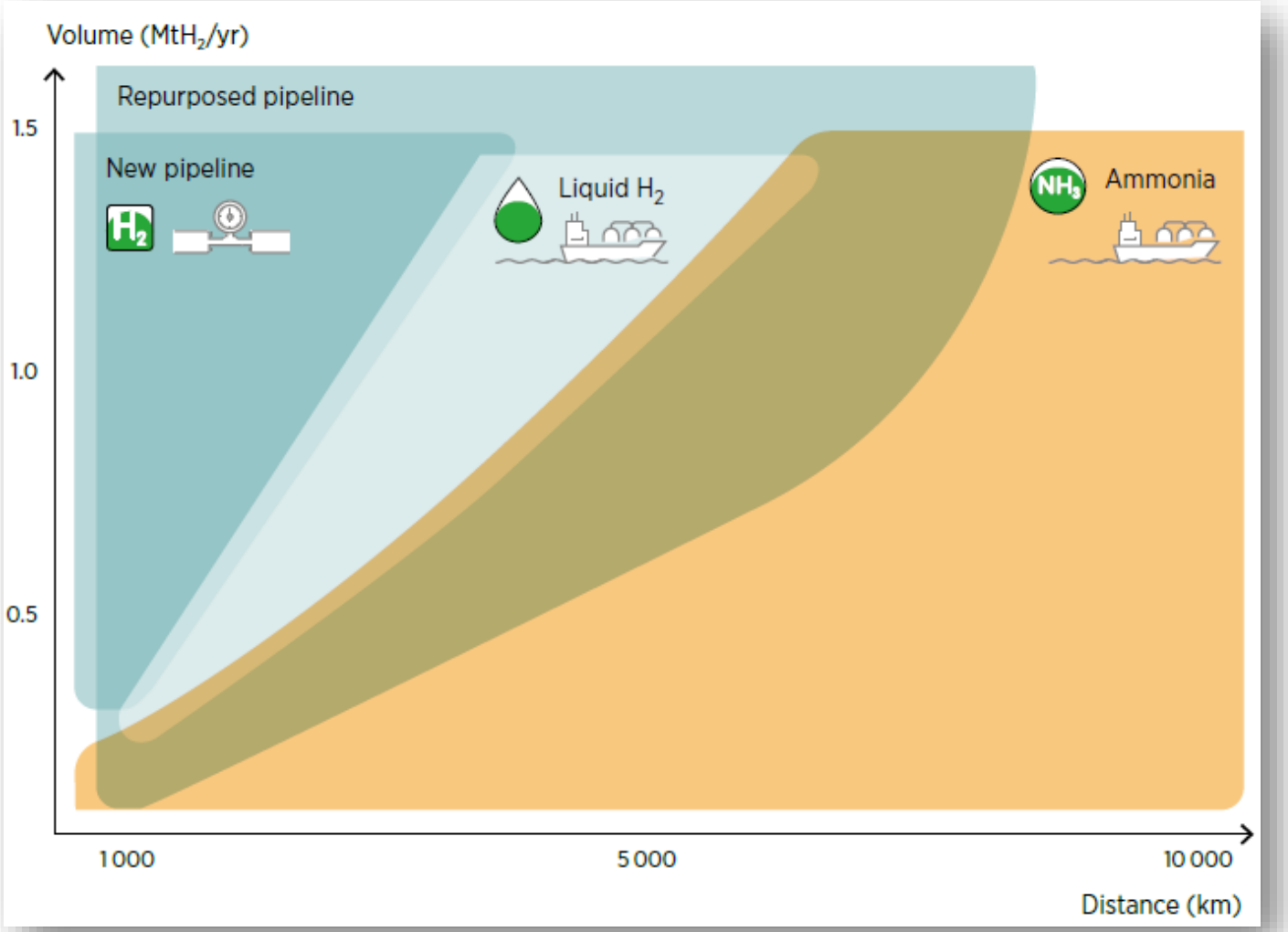


Ammonia is emerging a key part of a future global hydrogen trade flow

- Half of H_2 trade in the form of ammonia shipping

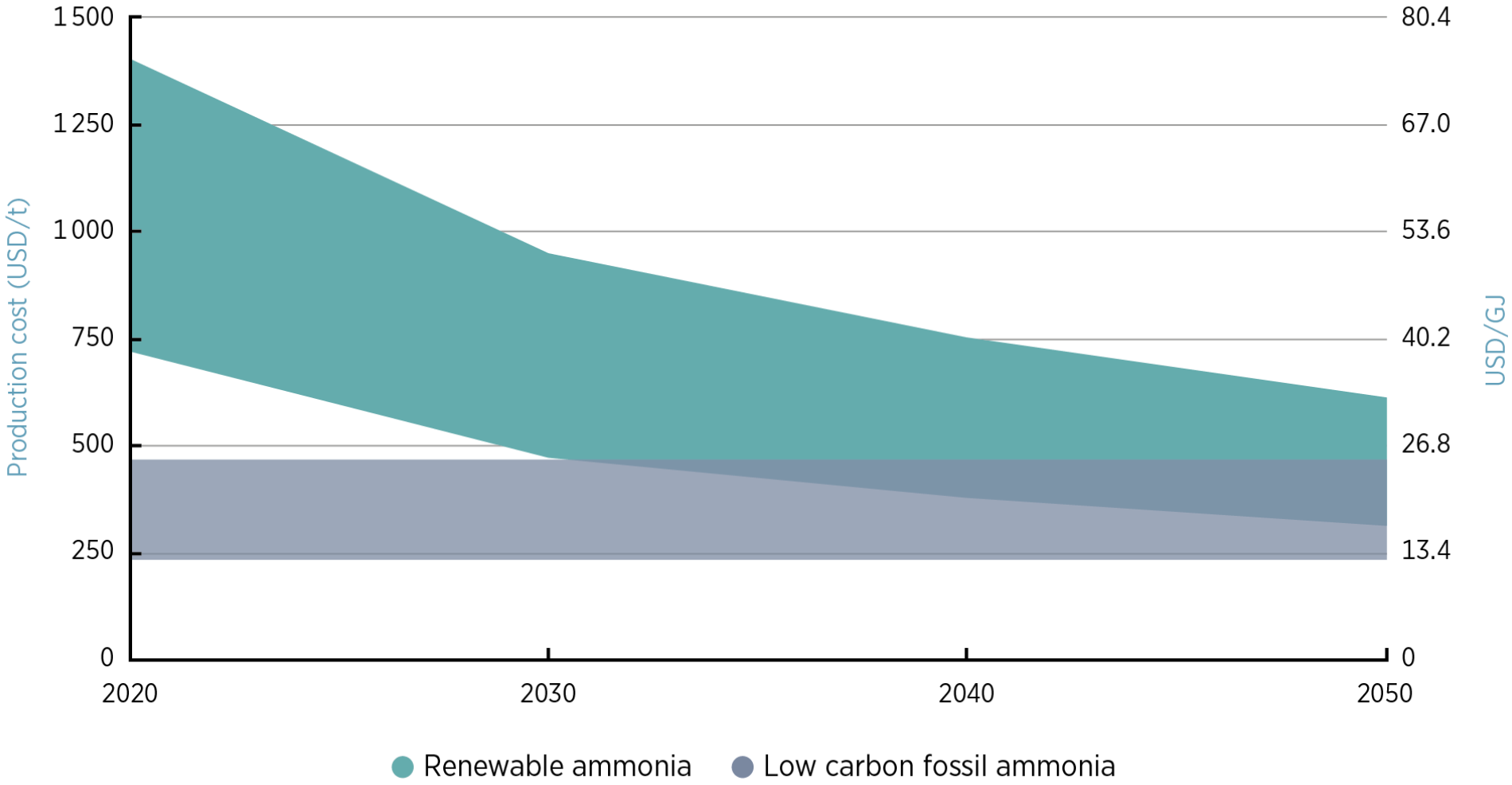


- Part I: Trade outlook for 2050 and way forward
- Part II: Technology review of hydrogen carriers
- Part III: Green hydrogen supply cost and potential



Production Costs - By 2050 costs expected to fall to USD 310-610/t

Current and future production costs of renewable ammonia



- Green ammonia already competitive in Europe versus Natural Gas ammonia

Note: Compared with production cost range for low-carbon fossil ammonia (USD 2-10/GJ)

Policy recommendations to close the cost gap

- **Establish a realistic carbon levy** - 60-90 USD/t CO2 for fossil-based ammonia with CCS and up to 150 USD/t CO2 to bridge the gap between fossil-based and RE ammonia.

- **Translate political will into policies** - strong, stable, and sustained regulatory measures for fuel standards and RE quotas or mandates.

- **Fund value chains rather than lone technologies -** support deployment by connecting the value chain across production, distribution, and utilization.

- **Develop trade strategies and supply chains by encouraging international co-operation** - i.e. between project developers, ammonia production companies, and ammonia users, to create jobs and foster competitive new industries for renewable ammonia. **Carbon Border Adjustment Mechanism (CBAM).**

- **De-risk investment capital via financial instruments –** e.g., enable grants, investments, loans, or loan guarantees, intermediate secured buyer of auctioned projects, etc.

Final remarks

- A transition to renewable ammonia is essential to limit the global temperature rise to 1.5C and bringing CO2 emissions closer to net-zero by the mid-century.
- The decarbonization of various sector depends on renewable NH3 i.e. chemical, agricultural, energy, and transport sectors.
- Under a 1.5° C aligned scenario, this transition would require to increase production by nearly four times. With growth driven by new energy uses that exceed current uses.
- Cheap H2 is the driver to achieve costs competitiveness.

RE ammonia is coming. We need to be ready to seize the opportunities.

Setting the scene presentation – Renewable Ammonia Technology Outlook

AMMONIA ENERGY ASSOCIATION

Kevin Rouwenhorst

Technology Manager – Ammonia Energy Association

Ammonia Energy Association

AMMONIA ENERGY ASSOCIATION

- The Ammonia Energy Association is a global industry association that promotes the responsible use of ammonia in a sustainable energy economy.

- **Supply**: decarbonize ammonia production.
- **Demand**: adopt ammonia in energy markets.

- **Members**: global and cross-sectoral.

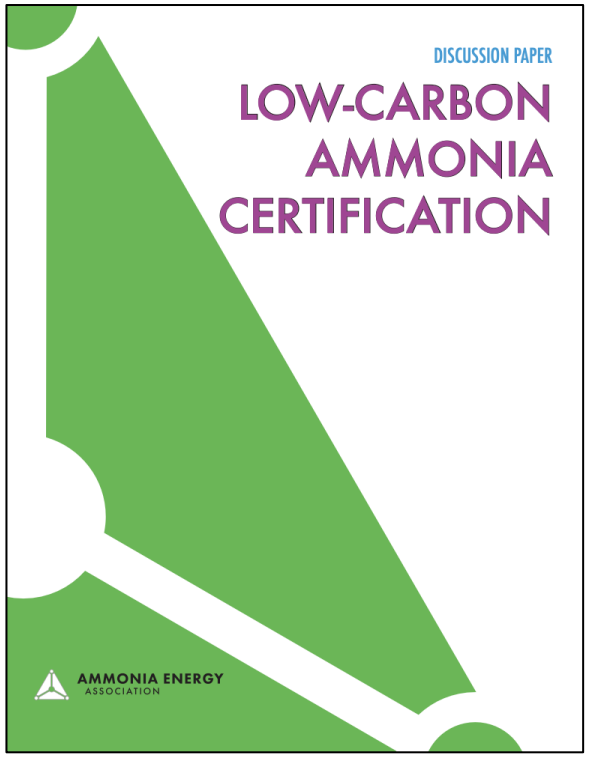
AMMONIA ENERGY ASSOCIATION

MEMBER LIST — May 2022

PLATINUM: bp, CF Industries*, CWP Global, Denbury Inc., The Hydrogen Utility*, InterContinental Energy*, KBR*, LSB Industries, Mitsui & Co., Monolith Materials, Nutrien*, OCI*, Starfire Energy*, Yara*. **GOLD**: AFC Energy, Airgas, Aker Clean Hydrogen, Asian Renewable Energy Hub, Casale*, Enaex, Engie, Equinor, Fortescue Future Industries, FuelPositive, Haldor Topsøe*, Hamilton Locke, Marnco, Mitsubishi Heavy Industries, Origin Energy*, Proton Ventures*, S&P Global Platts, Syzygy Plasmonics, thyssenkrupp Industrial Solutions*, Trammo, Trigon, Tri-State Generation & Transmission. **SILVER**: AES Gener, Air Products, Ammonigy, AmmPower, Amogy, Argus Media, BASF, Black & Veatch, Bureau Veritas, Burns & McDonnell, Casa dos Ventos, Consorcio Eólico, CRU Group, CS Combustion Solutions, Copenhagen Atomics, Cummins, EIFER, Enterprize Energy, Fertiberia, GenCell Energy, GTI Energy, Gunvor Group*, H2Site, Heraeus, Horisont Energi, HyFuels Holdings, IHI Americas, Inherent Solutions Consult, inodú, Intecsa Industrial, Johnson Matthey, Koch Fertilizer, Linde, Lotte Fine Chemical, Mabanaft, Maersk*, Mercuria, MineARC Systems, Mitsui OSK Lines, Nel Hydrogen*, Pacific Green Technologies, SagaPure*, Schoeller-Bleckmann Nitec, Shell, Skeiron, Sperre Industri, Stamicarbon, Talos Energy, Thorium Energy Alliance*, TotalEnergies*, Tsubame BHB, Universal H2, Wonik Materials, Woodside Energy. **MEMBERS**: AB Achema, Advanced Ionics, Advanced Thermal Devices, AHMON, Air Liquide, Airthium, Apex Clean Energy, Arizona Public Service, Ark Energy, Arranged, AustriaEnergy, Avaada Energy, Axetris, BLG, Brittany Ferries, C-Job Naval Architects, Carbon-Neutral Consulting*, CHZ Technology, ControlRooms, Cozairo, Cura IT, Danaos Shipping, Duiker Combustion Engineers, EI-H2, Energy Estate, Eneus Energy, ESNA, Evergy, Exmar, George Propane, GESCA, Greenfield Nitrogen, GTT North America, Idemitsu Kosan, Incitec Pivot, Ingenostrum, IT Power Australia, JGC Holding Corporation, John Cockerill, Jupiter Ionics, Keppel Infrastructure, Koole, Mainspring Energy, MAN Energy Solutions, MicroEra Power*, Moda, Nebraska Public Power District, Neology, Netsco, New Energy Technology, NGLStrategy, Nordex, Northern Nitrogen, NovoHy, NYK Energy Transport (USA), Oceanic Vessels, Oiltanking, Osaka Gas USA, Renewable Hydrogen Corporation Canada, SAFCell, SBM Schiedam, Shrieve Chemical Company, Syntex, Terrestrial Energy, Tokyo Gas, Unconventional Gas Solutions, UPC\AC Renewables, Vahterus, Varo Energy, Vopak.

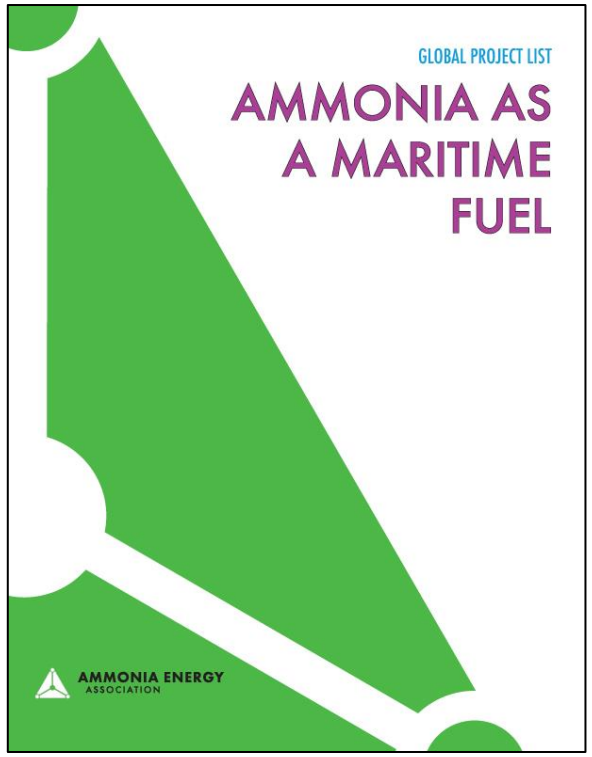
Activities Ammonia Energy Association

AMMONIA ENERGY ASSOCIATION

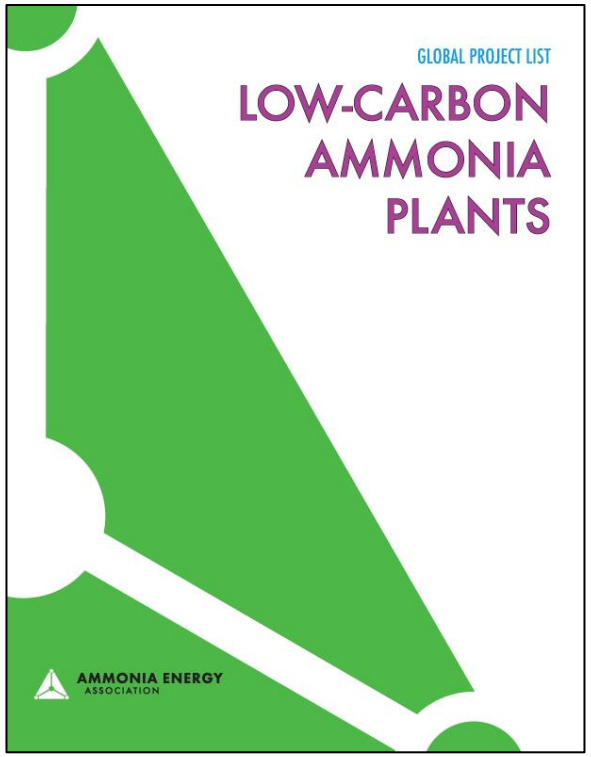


Develop certification scheme for low carbon ammonia

Innovation Outlook: Renewable Ammonia. (collaboration with IRENA)



Mapping maritime ammonia projects (+ webinars)



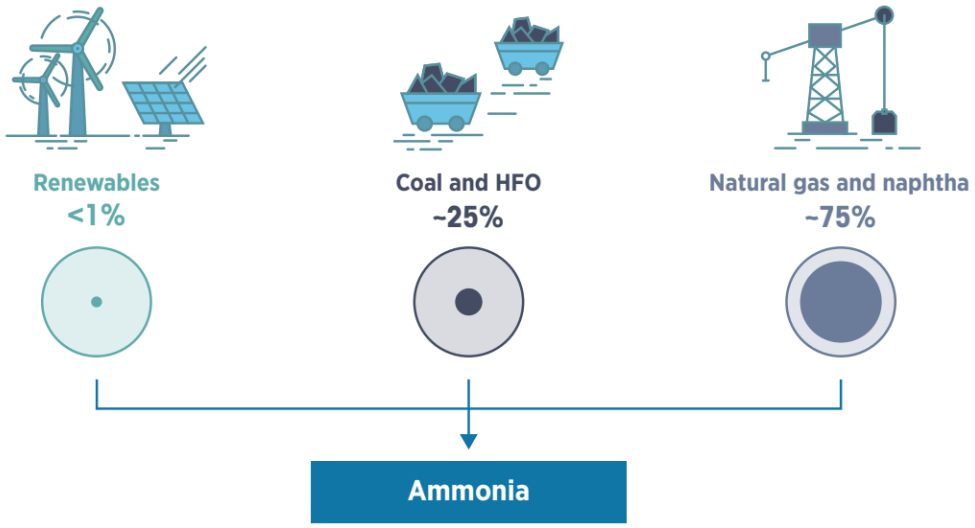
Mapping low carbon ammonia plants (+ webinars)

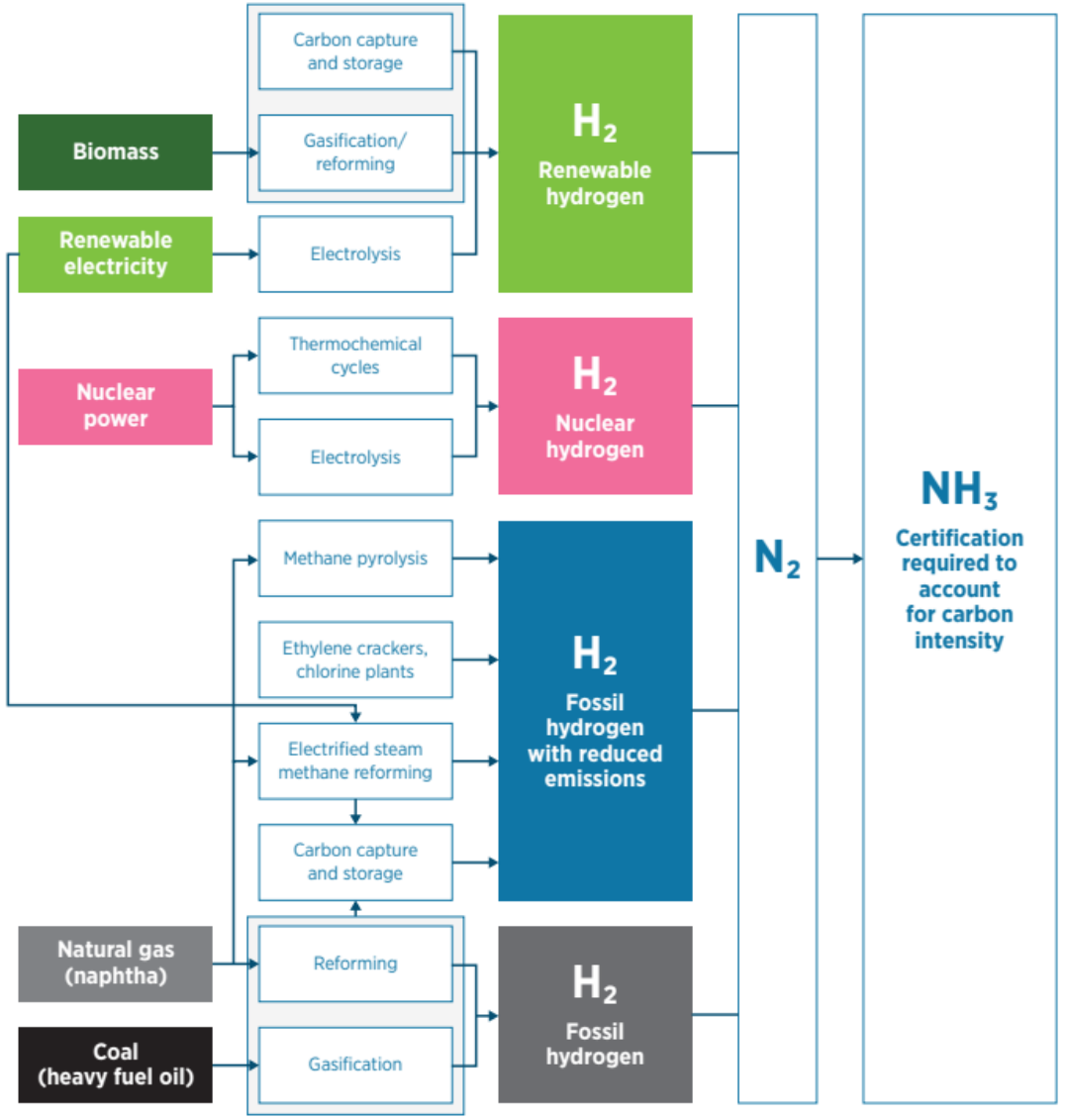
Ammonia production pathways

AMMONIA ENERGY ASSOCIATION

- **Ammonia** (NH_3) produced from **hydrogen** (H_2) and **nitrogen** (N_2) in the Haber-Bosch process
  - Hydrogen production typically accounts for >90% of total energy consumption of ammonia production, currently mainly fossil-based

- Ammonia production currently generates about **0.5 Gt CO_2 equivalent** annually (around 1% of global GHG emissions)
  - CO_2 emissions from fossil-based ammonia production vary depending on the feedstock, range 1.6-4 t CO_2 per ton ammonia

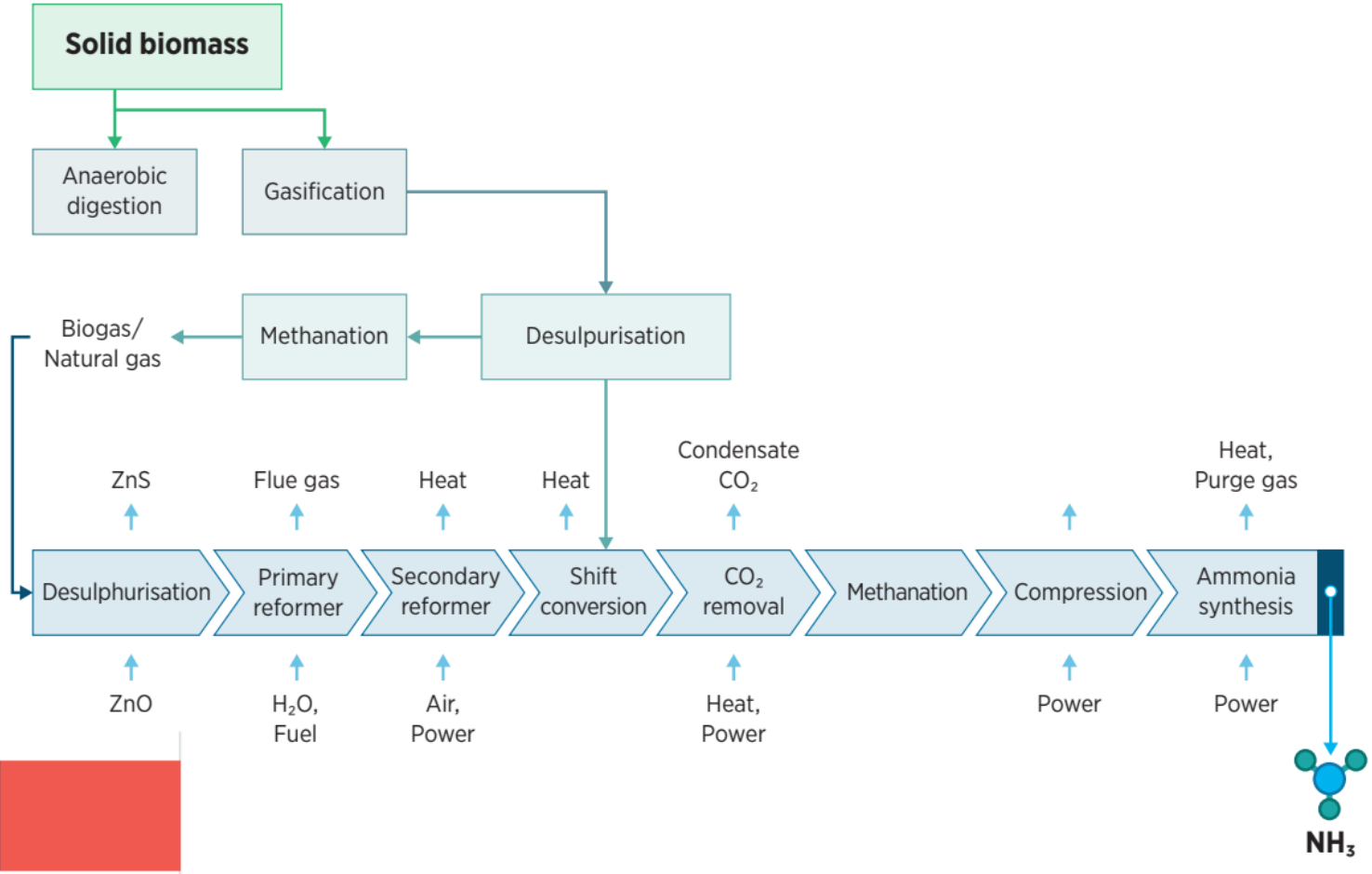


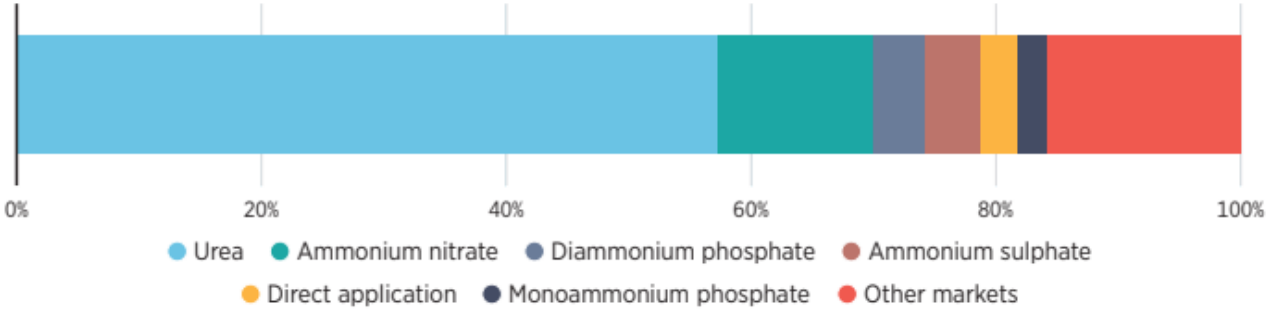


Renewable ammonia production: biomass

Biomass & biogas can replace natural gas and coal feedstock in existing facilities

- Cost premium on biomass (455-2000 USD per ton ammonia)
- Mainly of interest for **urea production** (carbon containing molecule, currently the biggest market for NH_3, 55% of NH_3 demand)
- Potential to **combine with CCS (BECCS)** to produce carbon negative ammonia / urea (offset emissions)



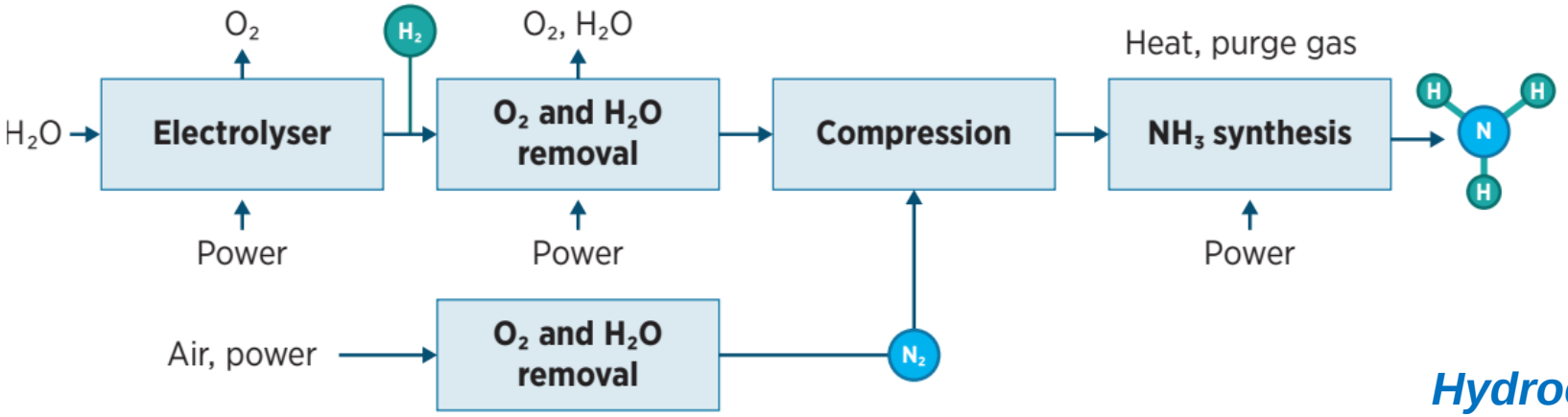


Renewable ammonia production: electrolysis

AMMONIA ENERGY ASSOCIATION

Ammonia can also be produced from **electrolysis-based hydrogen** with **low-carbon electricity**

- Electrolyser: Water (H_2O) converted to hydrogen (H_2) and oxygen (O_2) with electricity
- Low-carbon electricity: Renewables (solar PV, wind, hydropower), nuclear power, low-carbon grid
- 1920s: renewable ammonia commercial, based on alkaline electrolysis and hydropower (replaced by natural gas reforming due to cost)
- Nowadays shift to solar PV and wind (low electricity cost <20 USD/MWh in best locations)

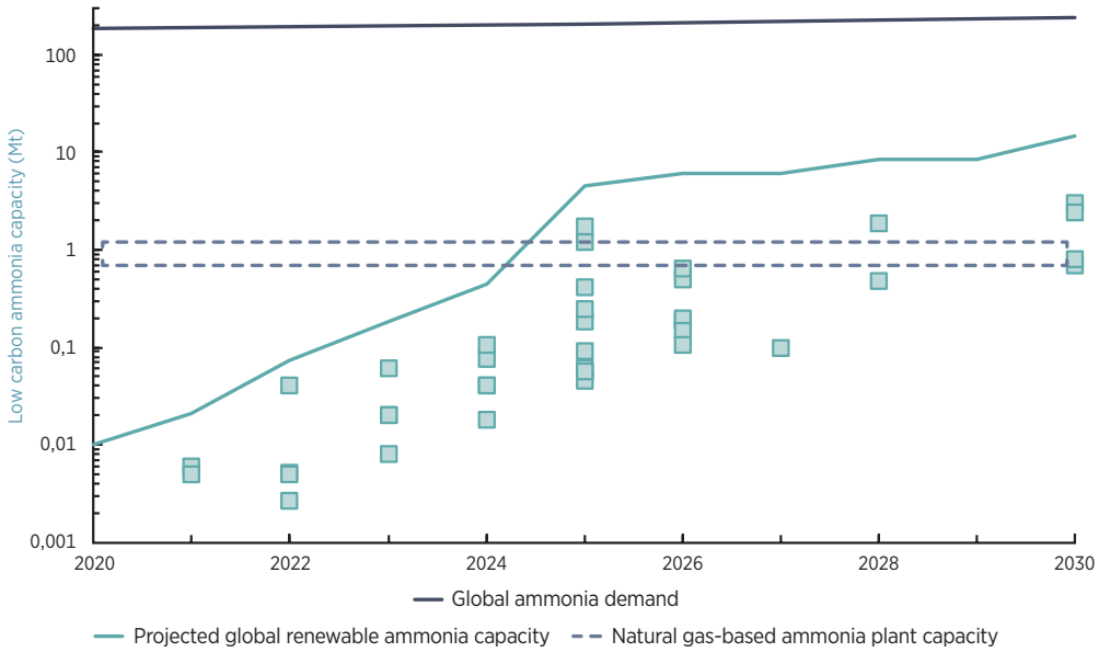


Hydroelectric ammonia plant in Cusco, Peru

Renewable ammonia production: electrolysis

AMMONIA ENERGY ASSOCIATION

Deployment of renewable ammonia:
- **2020-2025**: scale-up of renewable ammonia plants to GW scale
- **After 2025**: Numbering up of renewable ammonia plants



Announced renewable ammonia projects

2014: Wind to ammonia demonstrator (University of Minnesota)
- **Location**: Morris, MN (USA)
- **Type**: Newbuild
- **Capacity**: 0.03 kt-NH_3/y
- **Market**: fertilizers

2022: Solar PV revamp of existing ammonia plant (Fertiberia)
- **Location**: Puertollano (Spain)
- **Type**: Revamp (partial)
- **Capacity**: 6.1 kt-NH_3/y
- **Market**: fertilizers

2025-2026: World-scale renewable ammonia plant (NEOM)
- **Location**: NEOM (Saudi Arabi)
- **Type**: Newbuild (under construction)
- **Capacity**: 1200 kt-NH_3/y
- **Market**: Fuel or hydrogen carrier

نيوم NEOM

2035: Renewable energy hubs (Intercontinental Energy)
- **Location**: Pilbara (Australia)
- **Type**: Newbuild
- **Capacity**: 9900 kt-NH_3/y
- **Market**: Fuel or hydrogen carrier

Renewable ammonia production: electrolysis

AMMONIA ENERGY ASSOCIATION

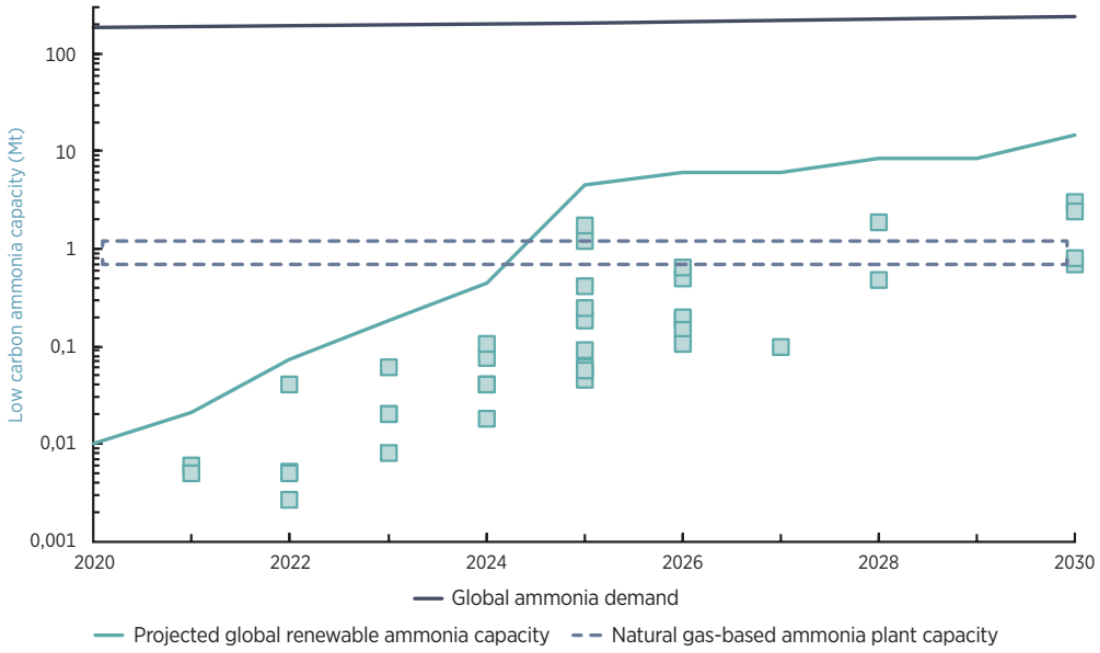
Deployment of renewable ammonia:

- **2020-2025**: scale-up of renewable ammonia plants to GW scale
- **After 2025**: Numbering up of renewable ammonia plants
- In line with ramp up on demand side (shipping, hydrogen carrier, power generation)

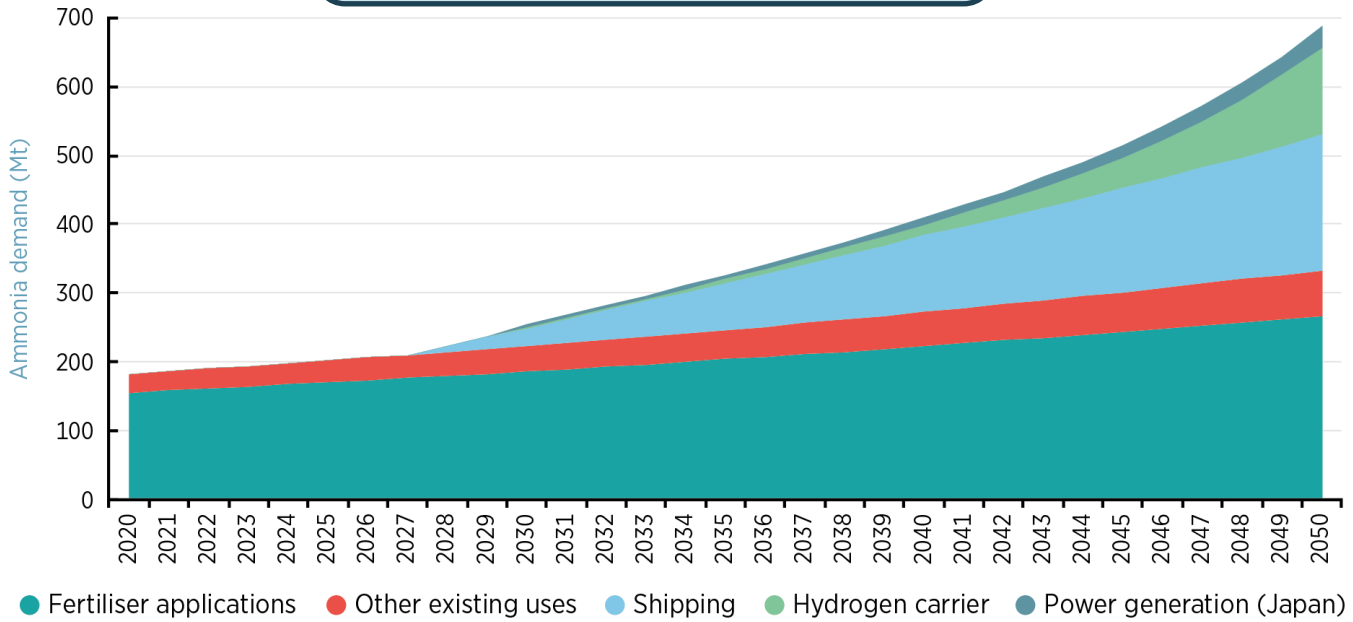
2023-2025: 2-stroke & 4-stroke ammonia-fueled maritime engines ready (MAN, Wärtsilä)

2023: Fossil-free fertilizers in Sweden

2024: 20% ammonia co-firing in coal-fired power plant (Japan, 50% ammonia co-firing by 2030)



Announced renewable ammonia projects



Projected ammonia demand (1.5°C scenario)

Conclusions: Industrial scale-up and technology readiness

The market for ammonia reaches 688 Mt by 2050 (1.5 °C scenario)

- **Fuel for maritime**: 197 Mt
- **Fuel for power generation**: 30 Mt (only counting Japan)
- **Hydrogen carrier**: 127 Mt
- In the long-term, renewable ammonia likely the main commodity for transporting renewable energy between continents

Demand side, technology demonstrations will be complete by 2025:

- Ammonia-fuelled vessels will be operating at sea, with two- and four-stroke engines available for new-builds and retrofits
- 1 GW power plant will be co-combusting ammonia with coal, with ammonia gas turbines, furnaces, and fuel cells available
- Fossil-free fertilizers will be commercially available by 2023

Industry is shifting towards renewable ammonia production:

- 15 Mt announced capacity by 2030 (~8% of current market, 54 projects announced, first projects already operational or under construction)
- **Project pipeline**: 71 Mt by 2040 (pending investment decisions)
  - >10% of the capacity that would need to be operational by 2050
- Renewable ammonia expected to dominate all new capacity after 2025

Panel Discussion

Opportunities and challenges for Green Ammonia

Moderator

Roland Roesch

Deputy-Director, IRENA Innovation and Technology Centre

Panellists

Alicia Eastman

President, InterContinental Energy

Ahmed El-Hoshy

CEO, OCI NV

Trevor Brown

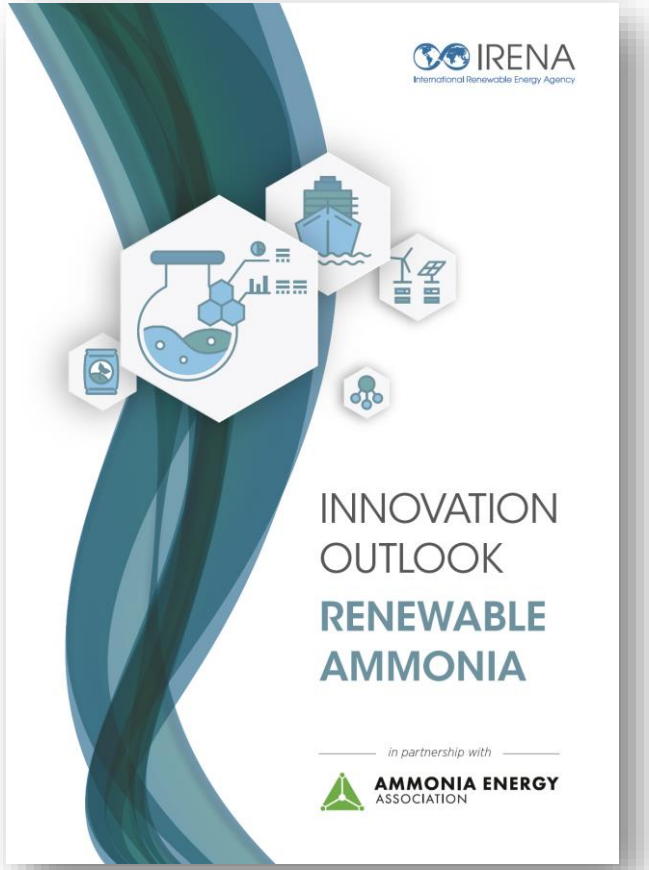
Executive Director – Ammonia Energy Association

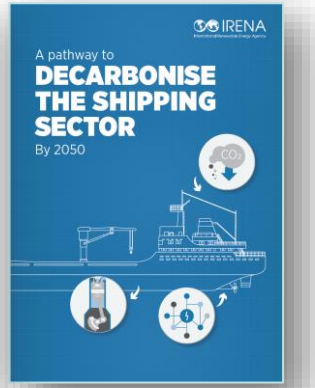
Closing Remarks

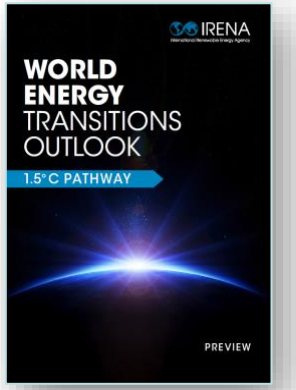
Dolf Gielen

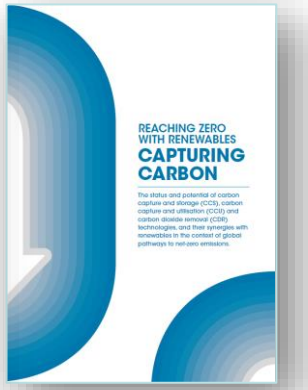
Director – Innovation and Technology Centre, IRENA

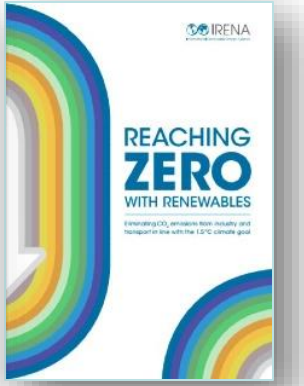
Thank you for joining us











www.irena.org

www.twitter.com/irena

www.facebook.com/irena.org

www.instagram.com/irenaimages

www.flickr.com/photos/irenaimages

www.youtube.com/user/irenaorg