PROTON VENTURES

FME presentatie

Energy Storage Day

12 oktober 2022

Empowering green ammonia and energy solutions

Ammonia — de vloeibare elektriciteit

Energy Storage Day 12 oktober 2022

door

Hans Vrijenhoef
Chairman to the Board
EVP - President Elect
Ammonia Energy Association

NH3 in het nieuws:

Germany's Olaf Scholz heads to Canada for energy talks

During the visit, the chancellor is set to sign a long-term deal to receive green hydrogen from Canada. German carmakers are keen to source minerals for electric vehicle batteries from the North American country.

Hydrogen Bank announcement

By ARNES BIOGRADLIJA 14/09/2022

In order to invest EUR 3 billion in the development of a potential market for hydrogen, the European Commission intends to establish a new European Hydrogen Bank.

BP evaluates hydrogen shipping options

Not all customers want fuel in the form of ammonia, says CEO Bernard Looney

BP is evaluating different transport options for its nascent hydrogen supply business and will provide updates on its plans in February next year. The firm is investing in green hydrogen supply projects and has acquired a 40.5pc equity stake in, and become operator of, the Asian Renewable Energy Hub—a planned

nergy solutions

Green | Cleaner Tech

Carlyle, GIC Back Green Ammonia With Investment in Eneus Energy

Deal allows Eneus to develop green ammonia projects starting in the US and UK.

By Angel Adegbesan +Follow

4 augustus 2022 12:30 CEST

Carlyle Group Inc. and Singapore's sovereign wealth fund GIC Pte. made a "strategic investment" in Eneus Energy Ltd. to support the company's push to develop green ammonia projects.

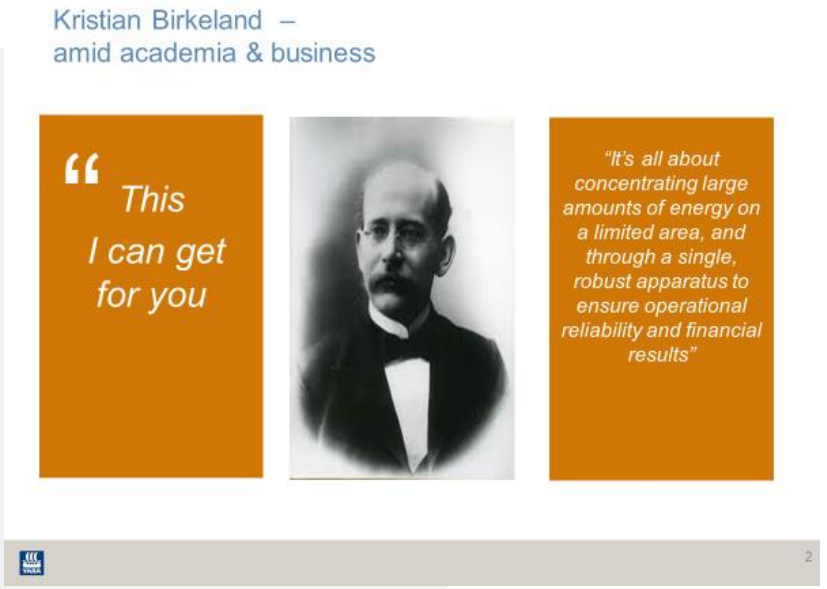
The backing allows Eneus Energy to continue to develop global projects involving ammonia made using renewable energy, starting with the US and UK, the companies said in a statement that didn't disclose the initial amount invested. The deal gives New York-based Carlyle and GIC the ability to invest

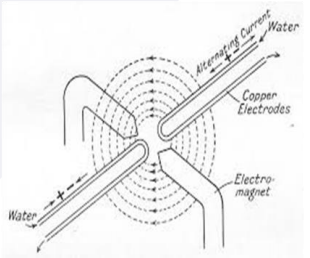
Wat is ammoniak

- NH3
- Ammoniak ca 99,9% (UK; ammonia!)
- Ammonia (verdund in water)
- In boerendiscussies Stikstof !?
- Productie wereld: 200.000.000.000 kg/jaar
- Bekend van Haber en Bosch (Nobel prijs)
- Voorkomt honger (1^{e} revolutie)
- Voorkomt klimaat crisis? (2^{e} revolutie)

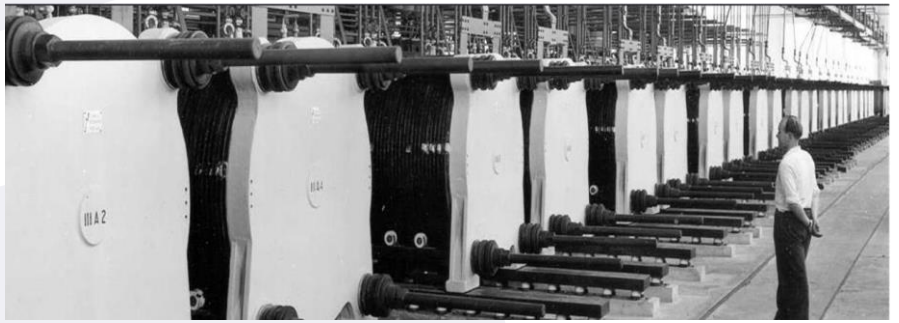
Hoe wordt ammoniak gemaakt

- Uit aardgas via Steam methane reforming SMR
  - CH4 + H2O ➔ H2
  - H2 + lucht (80% N2) ➔ NH3
- Van bijproduct H2
- Via natuur: onweer/ nitrificerende bacteriën/ rottingsprocessen
- En nu via Electrolyse:
  - Haber-Bosch 1e plant was ook op basis van elektrolyse

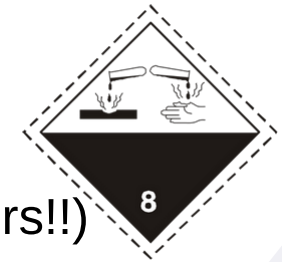




Eigenschappen ammoniak



Gevaarlijke stof UN1005
Vloeibaar gas -33 °C @ 1 bara (kamer temp: 6 barg)
Niet explosief in buitenlucht (wel onder druk)
LHV ammoniak = 14,1 MJ/l vs (H2 : 8,4 MJ/l) CH3OH 15 MJ/l
Agressief
Stinkt
(Licht) toxisch
Zeer makkelijk oplosbaar in water (sprinklers!!)
Niet corrosief voor meeste metalen
(Koper en messing uitzonderingen)



Veel bekend

NH3 Safety Data

Table 1: Toxicity Classes: Hodge and Sterner Scale (CCOHS)

			Routes of Administration			
			Oral LD50	Inhalation LC50	Dermal LD50	
Corresponding NFPA Ratings LC50	Toxicity Rating	Commonly Used Term	(Single dose to rats) mg/kg	(Exposure of rats for 4 hours) ppm	(Single application to skin of rabbits) mg/kg	Probable Lethal Dose for Man
	1	Extremely Toxic	1 or less	10 or less	5 or less	1 grain (a taste, a drop)
4 (0-100)	2	Highly Toxic	1-50	10-100	5-43	4 ml (1 tsp)
3 (100-500)	3	Moderately Toxic	50-500	100-1000	44-340	30 ml (1 fl. oz.)
2 (500-2500)	4	Slightly Toxic	500-5000	1000-10,000	350-2810	600 ml (1 pint)
1 (2500-20000)	5	Practically Non-toxic	5000-15,000	10,000-100,000	2820-22,590	1 litre (or 1 quart)
	6	Relatively Harmless	15,000 or more	100,000	22,600 or more	1 litre (or 1 quart)

Source: Canadian Centre for Occupational Health and Safety (CCOHS). Corresponding NFPA ratings addition by Norm Olson, NH_3 FA.

LC50, 4 hours, ppm - NH_3: 2000, Chlorine: 146.5, Methyl Isocyanate: 7.47

Multiple H2 - Routes (Pro's & Con's, @ 2,670 ton H_2)

- **NFuel (Ammonia)**
- $3H_2 + N_2 \Rightarrow 2\ NH_3$ or 1,5 molecule H_2 gives 1 molecule NH_3 **(no loss** of H_2 in the formation reaction)
- Approx. 178 kg H_2 per ton NH_3
- Cracking NH_3 to H_2 takes approx. 20-23% of initial H_2 quantity (why do this and not use directly the NH_3?)
- 15,000 ton NH_3 requires some **20,000 m³** storage volume

- **LOHC (Liquid Organic Hydrogen Carrier)**
- Thermo-chemical bonding of H_2 to organic hydrocarbons (e.g. MCH)
- Approx. 62 kg H_2 per ton LOHC
- Thermal energy needed to release H_2 from LOHC required, typically 25% energy loss
- Re-use existing infrastructure related to Oil & Petro Chemical Industry
- 43,000 ton LOHC requires some **55,900 m³** storage volume (but simpler system)

- **LH_2**
- Liquid at -253 °C, requirs some 3.9 (theoretical minimum) up to 16 kWh/kg H_2 in energy (10 - 50% of energy value is lost)
- 2,670 ton liquid H_2 requires some **38,000 m³** storage volume
- To compare, compressed H_2 gas at 200 barg would require for the same 2,670 ton the impossible volume of ca **188,000 m³**

- $CH_4 – CH_3OH$ (MeOH) : with fossil carrier
- The formation reaction requires CO_2 and generates less H_2 due to H_2O being formed, hence less attractive for energy purposes other than niche or difficult to abate sectors. Will the CO_2 resource be there in the future?
-

Why ammonia?

How many energy is stored in this storage tank?

225.000 Gigajoule (GJ)

~

62.5 million Kwh

How many solar panels are needed to produce this amount of energy in a month?

1.8 million solarpanels

~

500 MW installed capacity

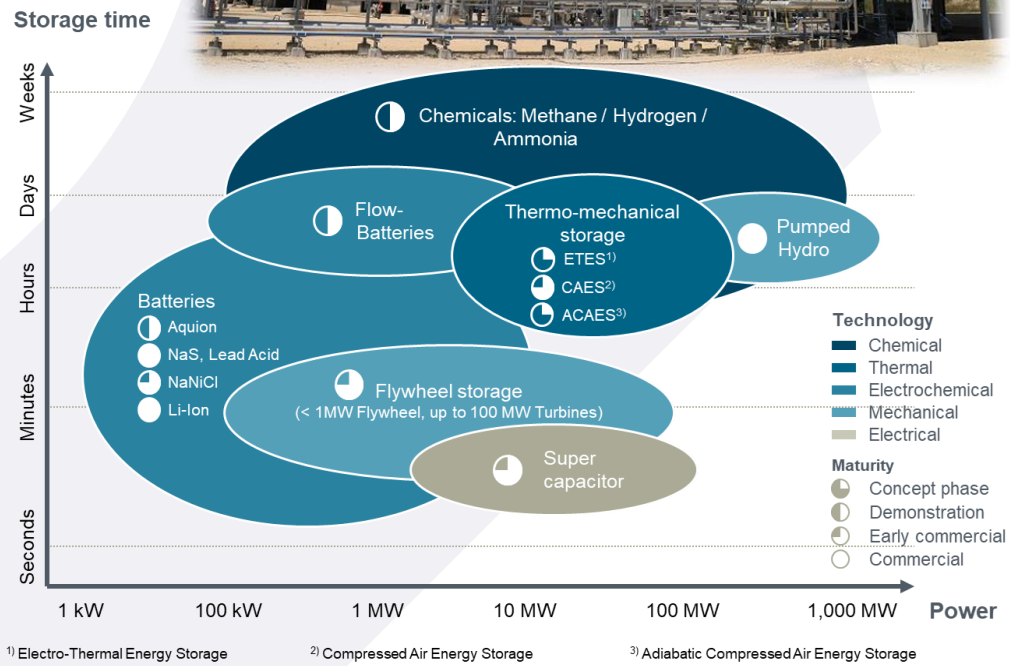
Which surface is needed for this production?

425 hectare

~

>660 soccer fields

Assumptions: Yield PV 0.3; 275 Wp per solar panel; 4300 panels per hectare;



Source: Siemens presentation, 1st European NH_3 Conference, 19/05/2017

Ammoniak applicaties (bestaand), misschien onbekend

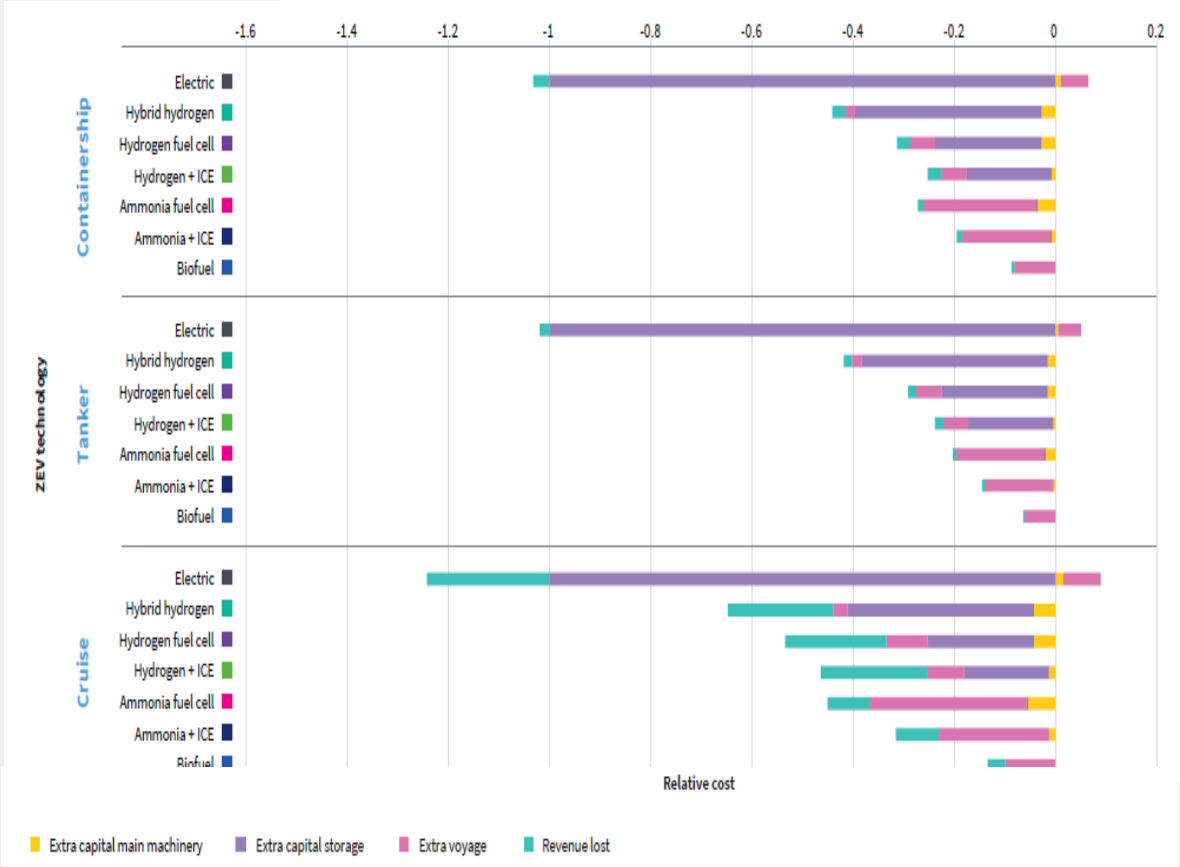
Ammoniak, de ideale waterstof drager

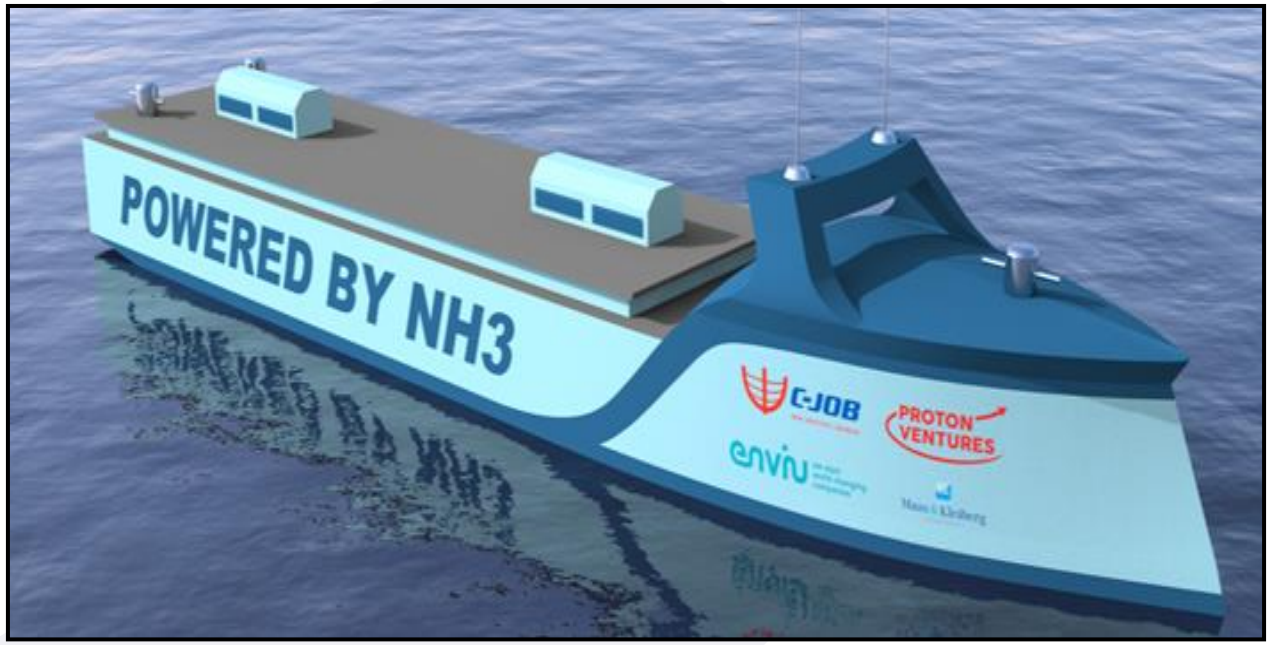
- Sustainable energy can be stored in the form of ammonia as a hydrogen carrier.
- Ammonia has a relative high energy density in general but as a carbon free component one of the highest.
- Ammonia contains in fact more hydrogen per molecule than the product hydrogen and that has advantages in storage and logistics (108 kg H_2/m^3 NH_3^{warm} or 121 kg H_2/m^3 NH_3^{cold}).
- Ammonia can be easily stored and transported with excellent track record by pipeline, truck, rail or ship.

Anhydrous ammonia (warm)	Value
Transport pressure (bar)	8,6
Transport temperature (°C)	20
Molar mass (kg/kmol)	17
Density (kg/m³)	611
H_2 (kg/m³)	**107.8**

Pressurized hydrogen	Value
Transport pressure (bar)	300
Transport temperature (°C)	20
Molar mass (kg/kmol)	2
Density (kg/m³)	23.7
H_2 (kg/m³)	**23.7**

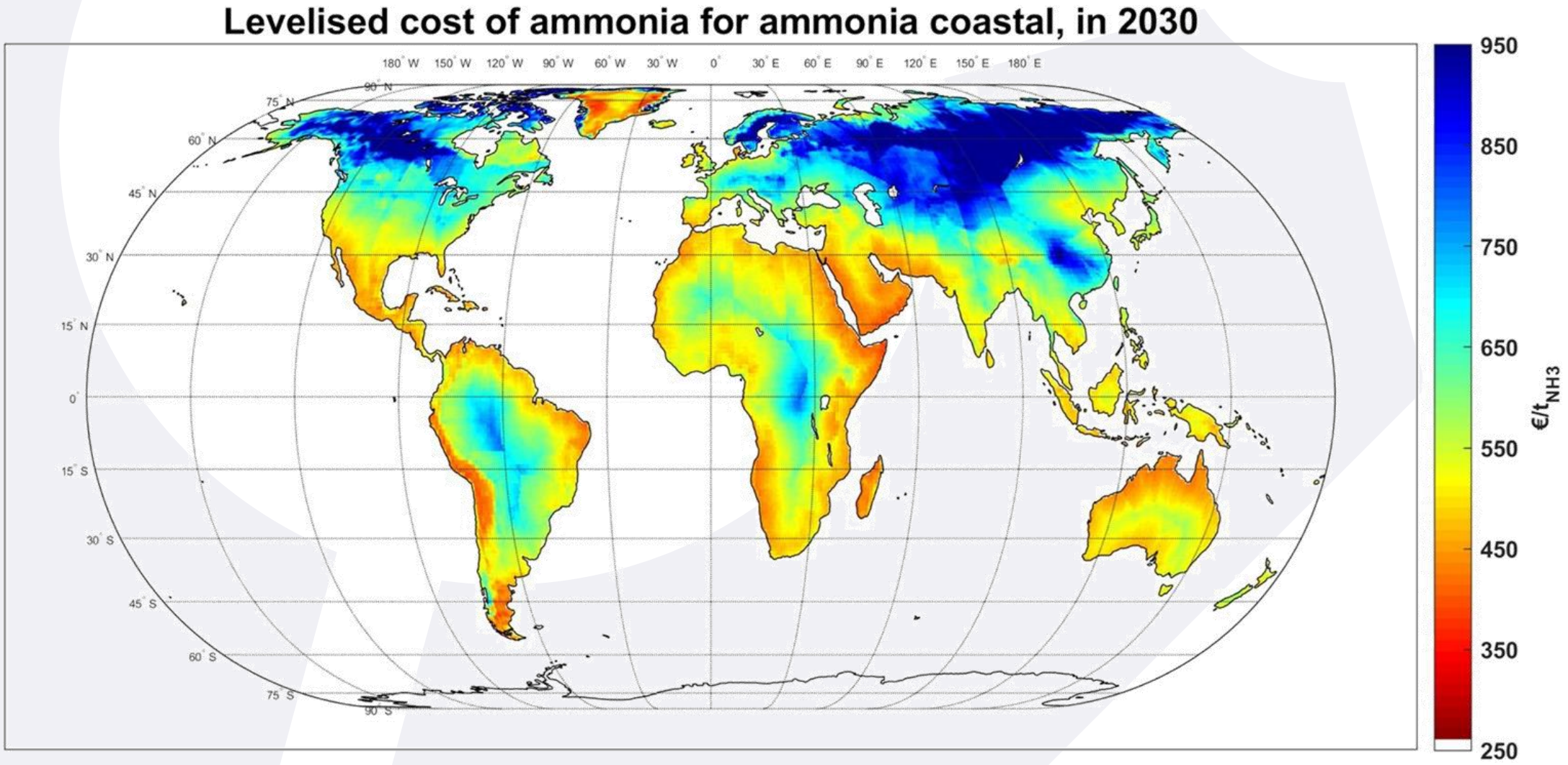
Ammoniak als maritieme brandstof



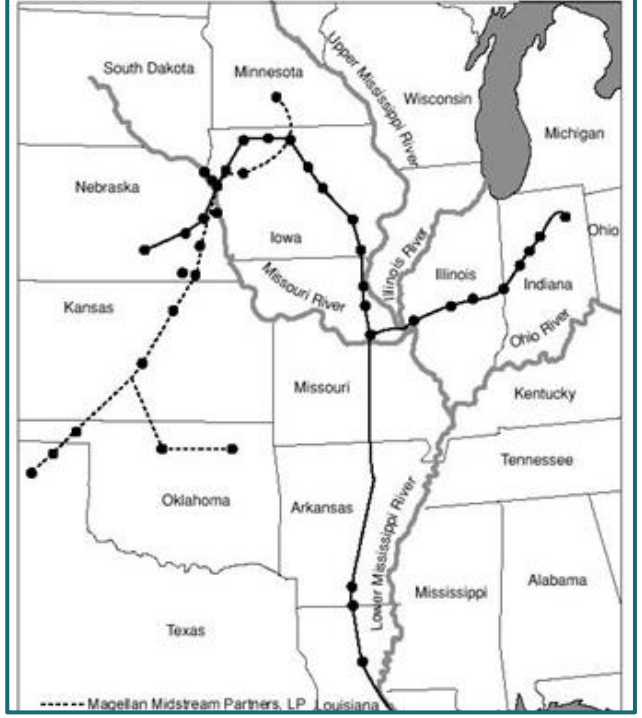


- C-Job – Ammonia as ship's fuel
- MAN Energy Solutions' ammonia engine
- Korean register – Ammonia Preferred Maritime Fuel
- World's first high-power fuel cell powered by green ammonia

Ammonia; vloeibare duurzame energie



[1] https://www.sciencedirect.com/science/article/pii/S0306261920315750



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Ammonia storage and transport

With Ammonia, There's no "Chicken or Egg" dilemma

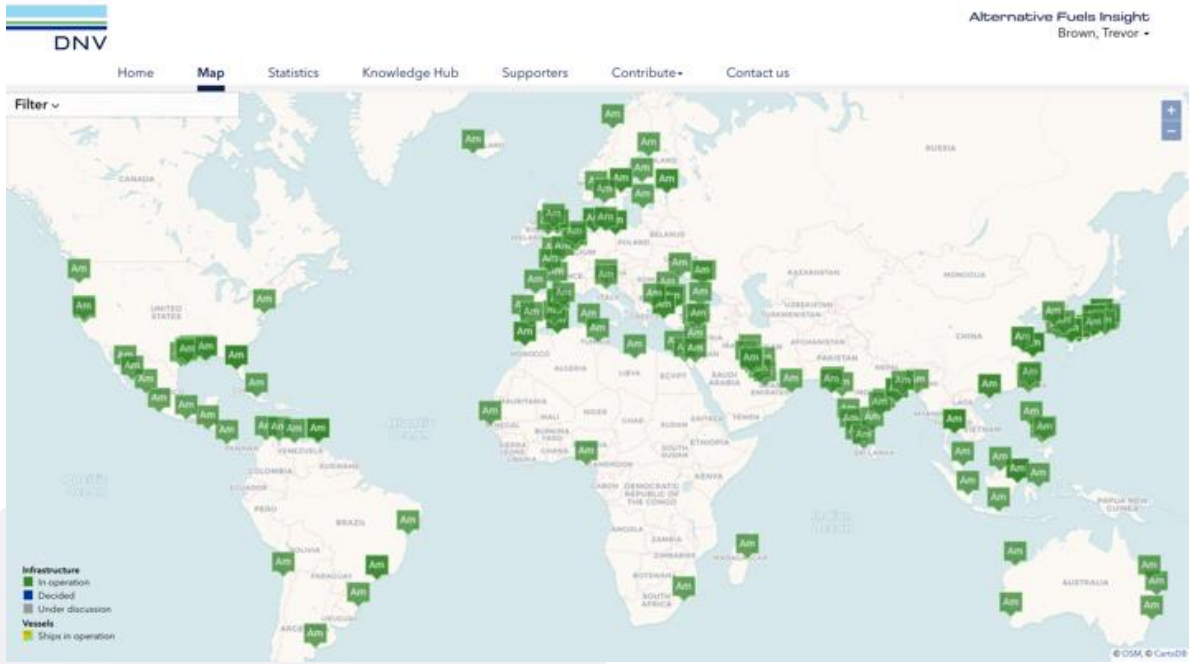
Bestaande Ammoniak markt

Ammonia is the 2nd most produced chemical worldwide

- Global production: ca 200 Mt
- International trade: ca 18 Mt
- 196 ports with infrastructure for bunkering (import/export terminals)

- 150 years of safety knowhow, codes and standards, regulations, technologies, training.

- Significant anchor markets and existing infrastructure enable expansion into new markets.



Global operational ammonia terminals (import/export tanks and infrastructure), DNV GL's Alternative Fuel Insight platform, https://afi.dnvgl.com/Map

Proton Ventures – Ambassador of Green Ammonia

Since 2001 Proton Ventures pioneered in the **(green) ammonia industry** by designing the largest ammonia terminals of Europe and sustainable ammonia plants.

Proton has been an ambassador for green ammonia by:

- Being initiator/organiser of the European **NH_3 event**
- Being partner of the **Ammonia Energy Association**, Arab NH_3 Fertilizer Association, Energy Storage NL, Voltachem and many more
- Providing lecturers to governmental institutes
- Providing Ammonia webinars and trainings

Over Proton Ventures

EMPOWERING STORAGE SOLUTIONS

Chemicals, green energy and beyond

Since its foundation in 2001 Proton Ventures pioneered in the (green) ammonia industry. Ranging from large-scale ammonia storage and loading facilities to our modular NFuel concept and ammonia decomposition to obtain hydrogen the allowing for complete coverage of the entire value chain of (green) ammonia is covered

Our business segments:

1. Project development services.
2. Ammonia (engineering) solutions.
3. Innovation & R&D.

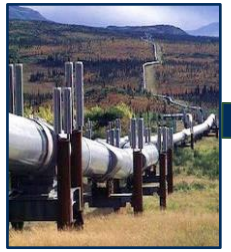
From concept to operational facilities, Proton Ventures offers consultancy support, project development management, feasibility study and FEED study engineering services, up to and including the actual EPC works.

Optimaliseren van ammoniak in (nieuwe) ketens

1. Project Development

Renewable Power

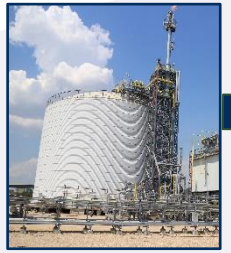
H_2 Production & Conversion



Local gas distribution

Storage & Export

Transport

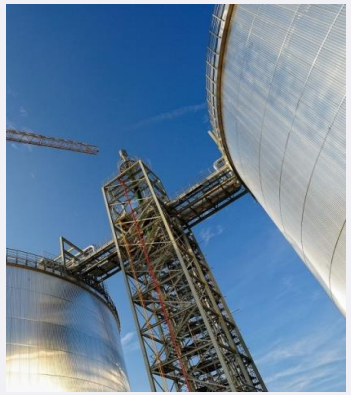


Storage Design & operation

Local distribution

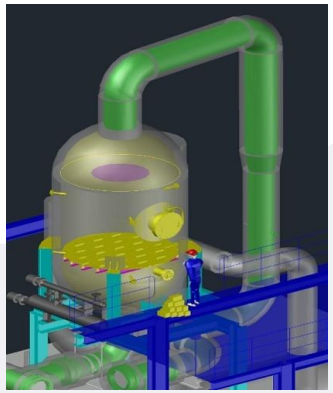
Decomposition H_2 or NH_3 sales

2. Ammonia Solutions



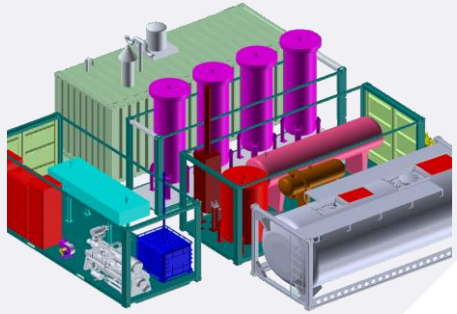
NH_3 & Energy storage

NH_3 Production



NOx & N_2O removal

3. Innovations



Ammonia decomposition

Ammonia as fuel / energy carrier

Proton Ventures – Partners for Green Ammonia

- Over the past decade Proton Ventures teamed up with stakeholders within the complete **Power-2-ammonia-2-application** chain, such as:
- **Establishing the Transhydrogen Alliance**
- Partnerships with prominent Technical companies (I.e Casale, Halder Topsoe, Vicoma, Battolyser, Duiker Combustion, etc.).
- Teaming up with local partners, universities, research institutes and governmental authorities



NH_3 (energy) storage & handling

- Refrigerated storage tanks (largest of Europe)
- Main & holding compressors
- Marine & railcair (un)loading facilities
- Railcar loading facility
- Utilities

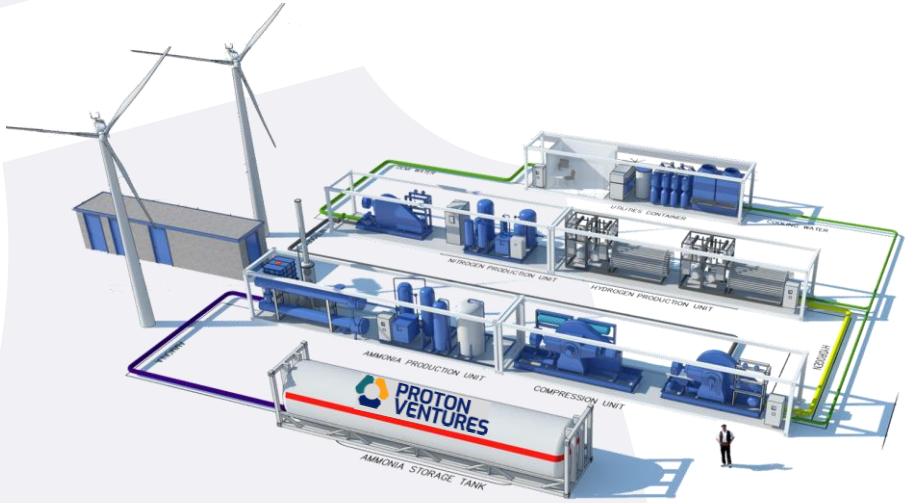
Terminal business references

- 2x30.000 Metric ton Estonia (2009)
- 10.000 Metric ton Bulgaria (2013)
- 2x30.000 Metric ton Estonia (2019)
- 12.000 Metric ton Bulgaria (2021)

NH_3 production

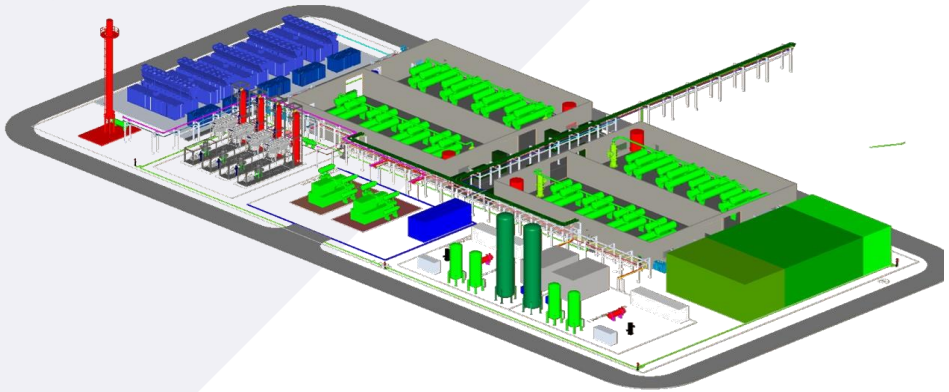
Small Scale (Decentralised application)

- NH_3 plant capacities ranging from small scale (1 – 80 kton /annum). Typically includes small (pressurised) ammonia storage.
- Services range from Project Development, (P)FS, FEED/FID to EPC-(M).
- Standardised designs for small scale solutions with Minimum CapEx & optimized OpEx approach.



Medium & Large Scale (centralised application (export))

- Includes both Ammonia plants and Ammonia Storage & handling facility (see former slides);
- NH_3 plant capacities starting with 80 kton/annum, to be build up to >1 million ton/annum plants.
- Services range from Project Development, owner's engineer, Scoping, (P)FS, FEED/FID, and EPC-M.
- Project dedicated design configuration based on availability of renewables.



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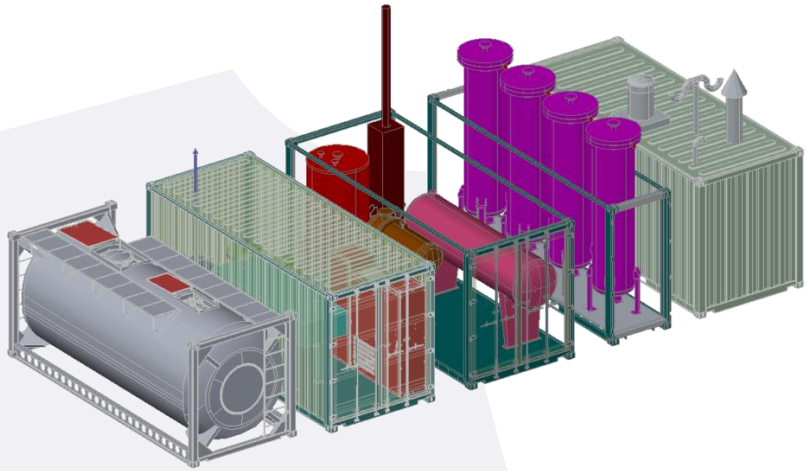
Empowering green ammonia **and energy solutions**

Innovations; Power2ammonia&ammonia2Power

As a frontrunner in de-carbonising the energy and agricultural sectors, we rely on our innovative solutions generated through in-house and consortium-based R&D. From innovative integrated solutions to ammonia de-composition technology



Energy Carrier/Hydrogen Carrier

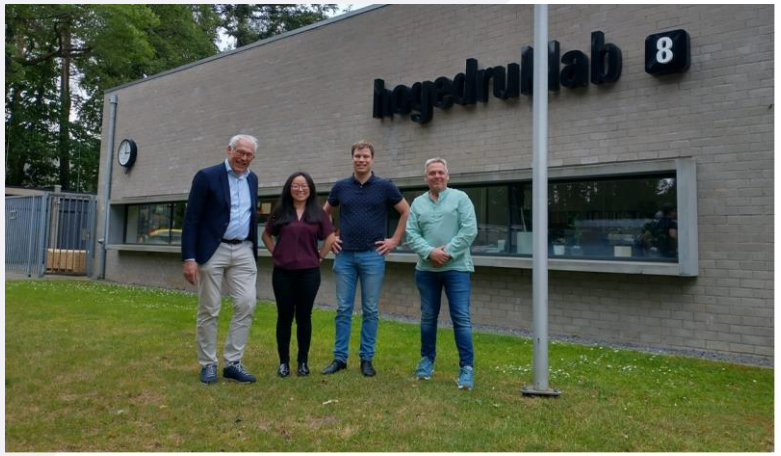
- NH_3 can be convert back to H_2 by cracking technology

Fuel cell

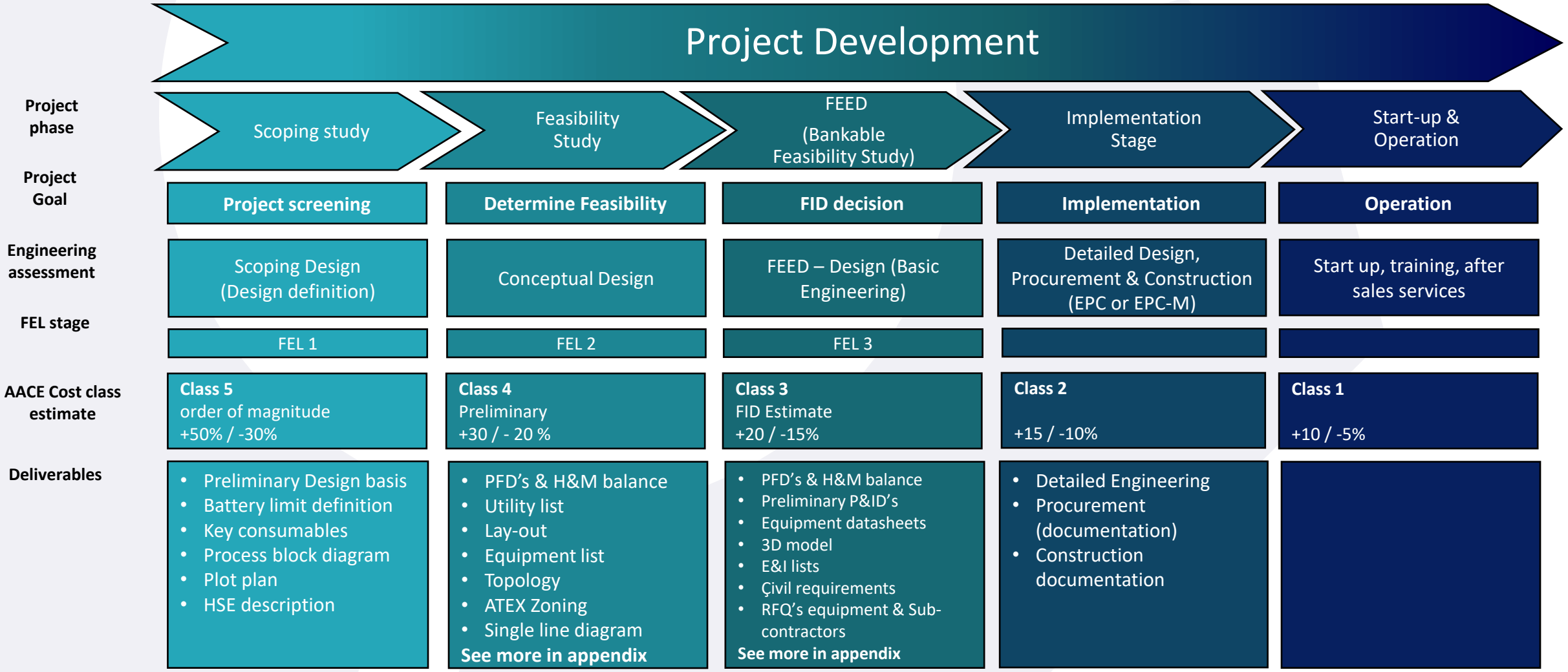
- Studies are performed using NH_3 as a reactant

Combustion engine

- Test are being performed to use NH_3 as a carburant for car engines



Proton Ventures' project stage definition



FEL definition description

AACE class definition description

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Empowering green ammonia **and energy solutions**

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Empowering green ammonia **and energy solutions**

(Green)NH_3 Production Practical Experience

#>100(45) Performed business analysis for (green)ammonia production

#>25(10) performed Feasibility Studies for (green) ammonia production

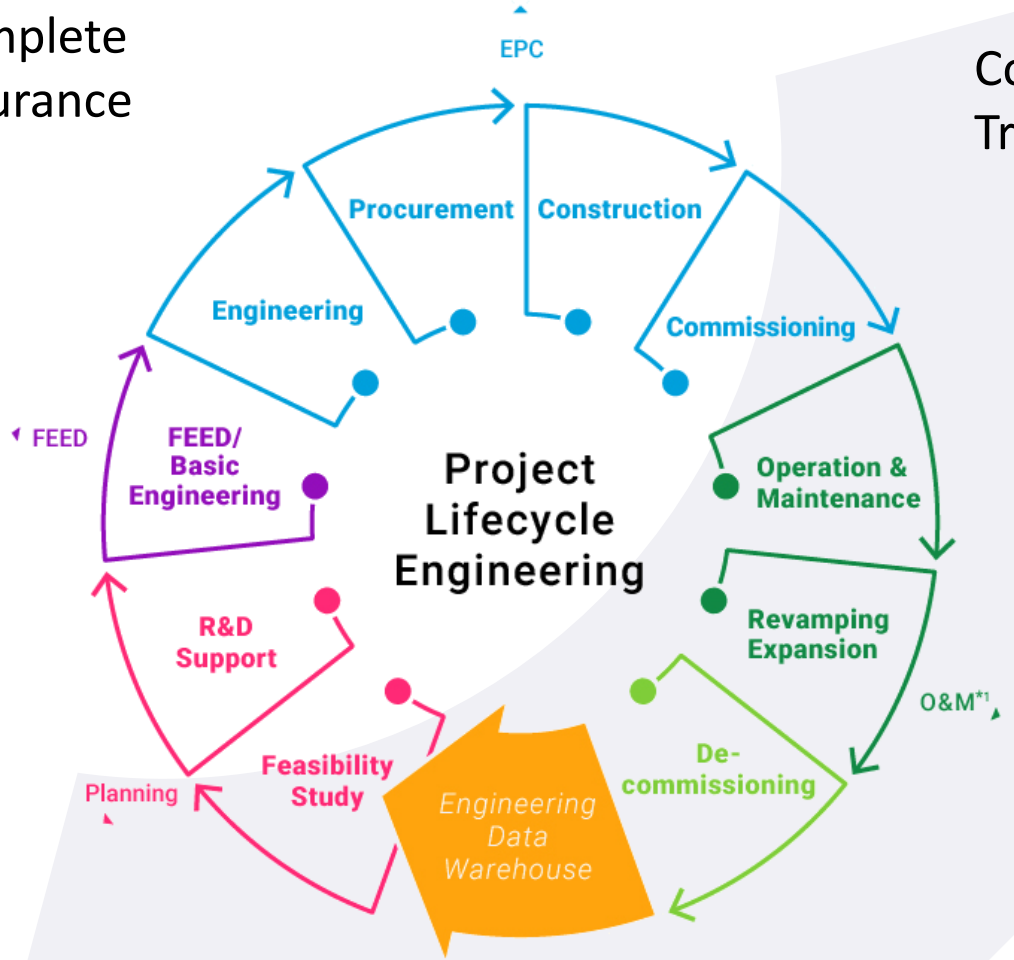
#>5 Performed Basic Engineering Packages (BEP) for (green) ammonia production

Project lifecycle & services

Optimised **procurement** of complete system equipment, quality assurance through in-house inspection

Basic & Detailed engineering, Fixed turn-key price ISBL & OSBL

Feasibility studies
Client's Site visit, Quick Scan-Financial Analysis, Definition of ISBL scope & OSBL scope
→ Greenlight for further steps



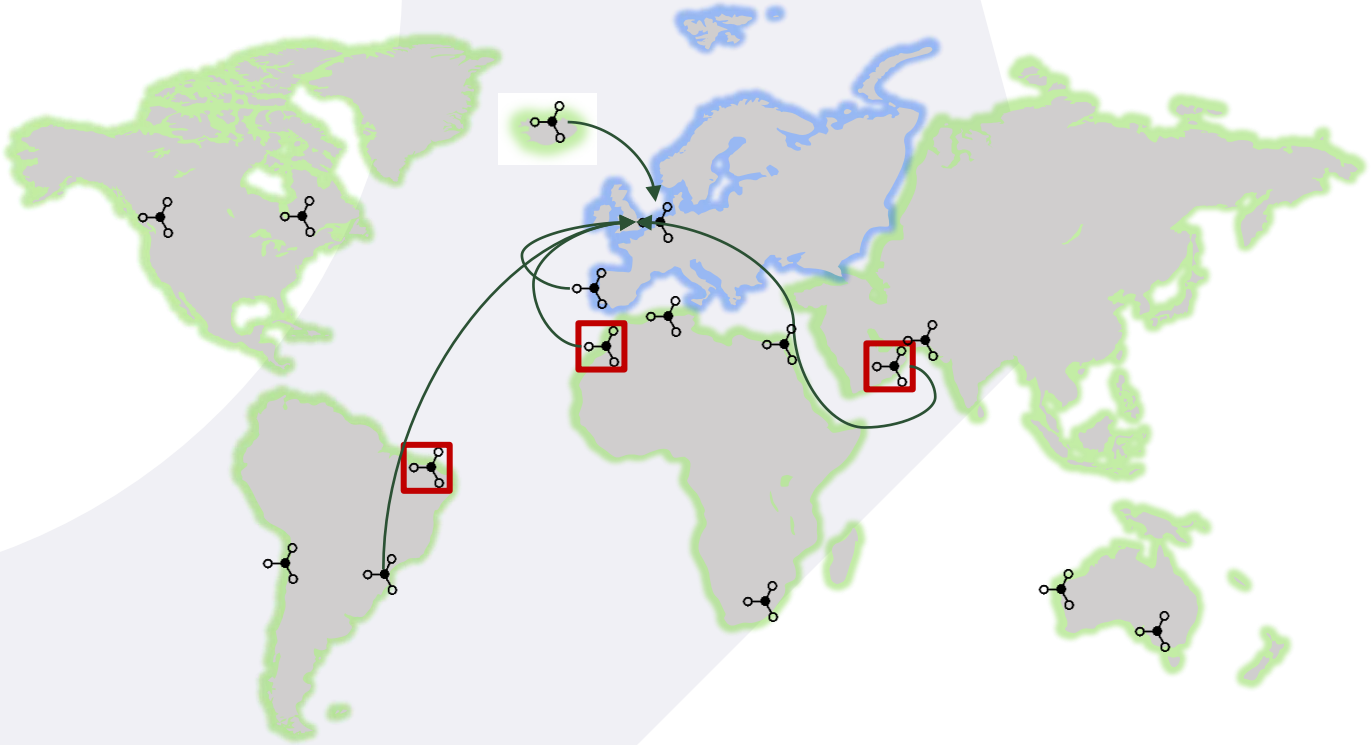
*1 Operation and Maintenance

Construction & Commissioning & Training:
EPC approach and fast start-up with experienced in-house personnel

Remote monitoring, plant management, maintenance contracts

Het doel / mogelijkheden om te vergroenen in Europa

- Through recent political and technological developments there is an opportunity to set up new green energy supply chains between sun-and wind rich countries that bring future supply and demand together.
- The **THA** consortium wishes to work together with specially selected partners in specific countries to create a new export industry and all related benefits.
- Thanks to unique technical solutions and the combination of industry experts in each part of supply chain **THA** can start this supply chain within 3 years from today, with large scale up potential.
- **Let's build the future together.**



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Thank you

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