Developing the logistics infrastructure to facilitate the Energy Transition

Green ammonia production distribution and Technological Innovations

Botlek Studiegroep

29.04.2021
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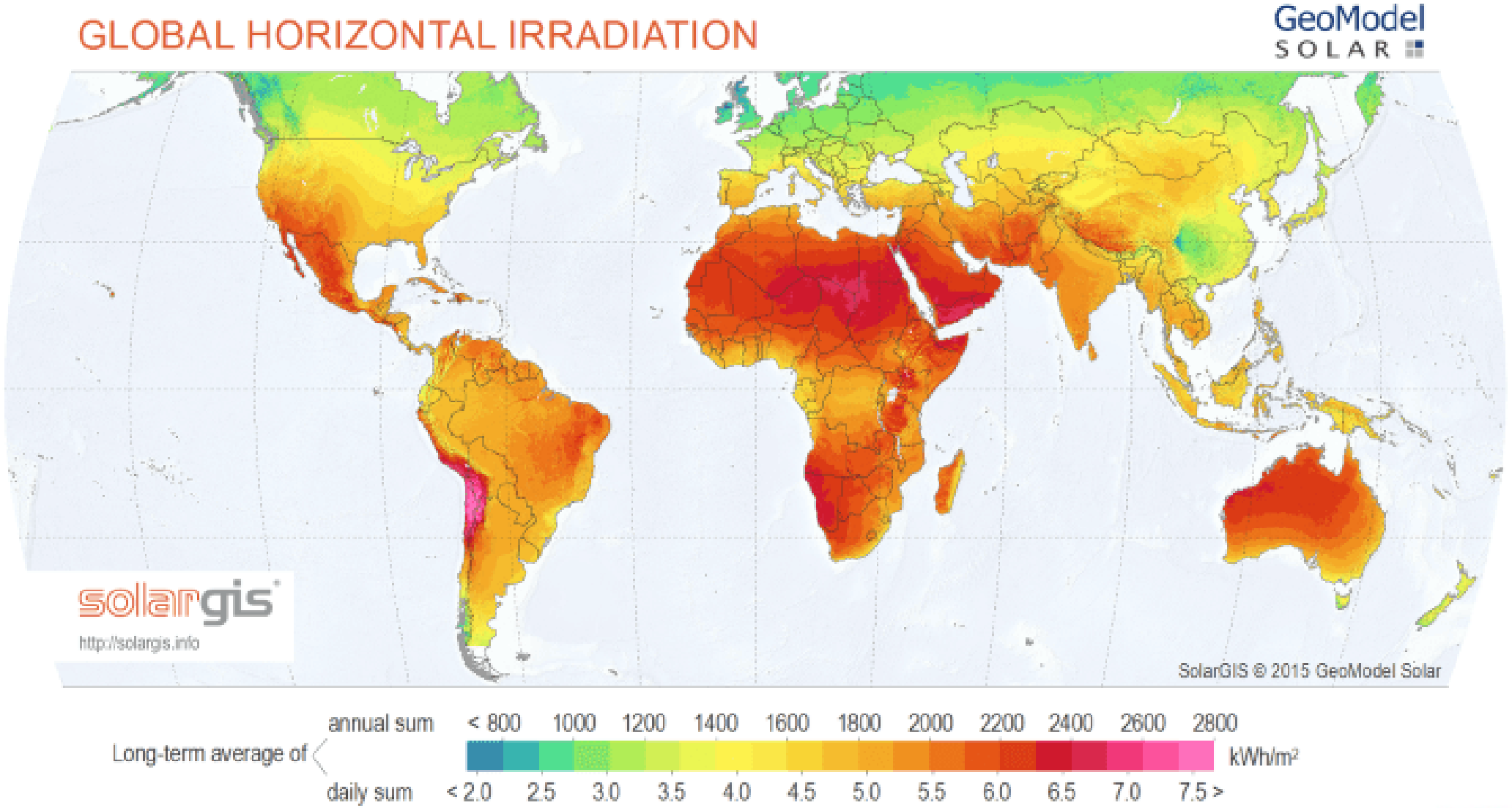
Ammonia, the new oil



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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

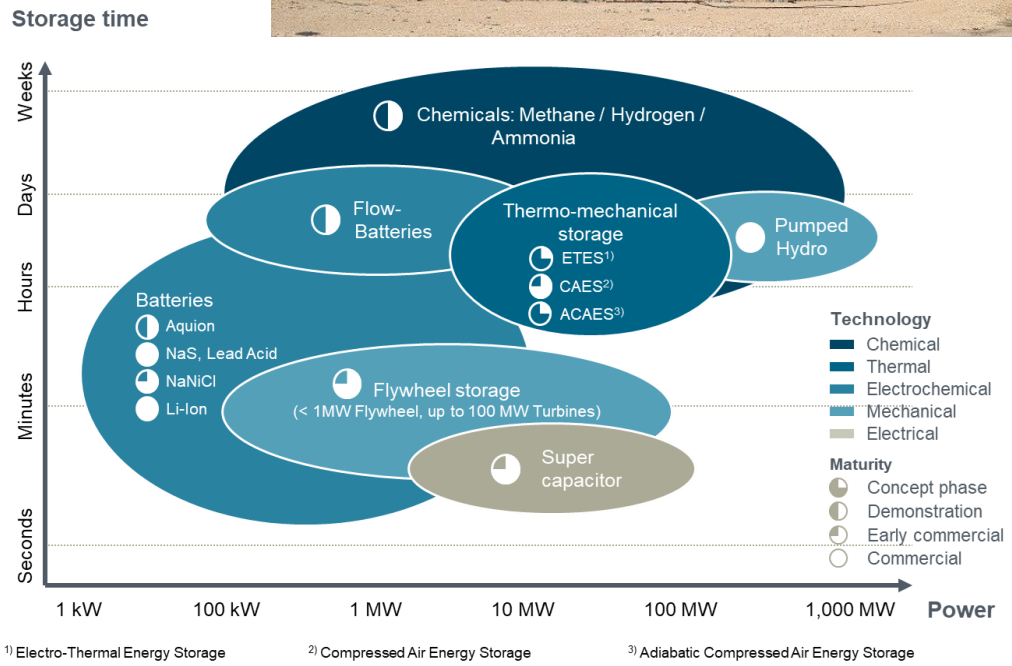
Which surface is needed for this production?

425 hectare

~

>660 soccer fields

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



1) Electro-Thermal Energy Storage 2) Compressed Air Energy Storage 3) Adiabatic Compressed Air Energy Storage

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

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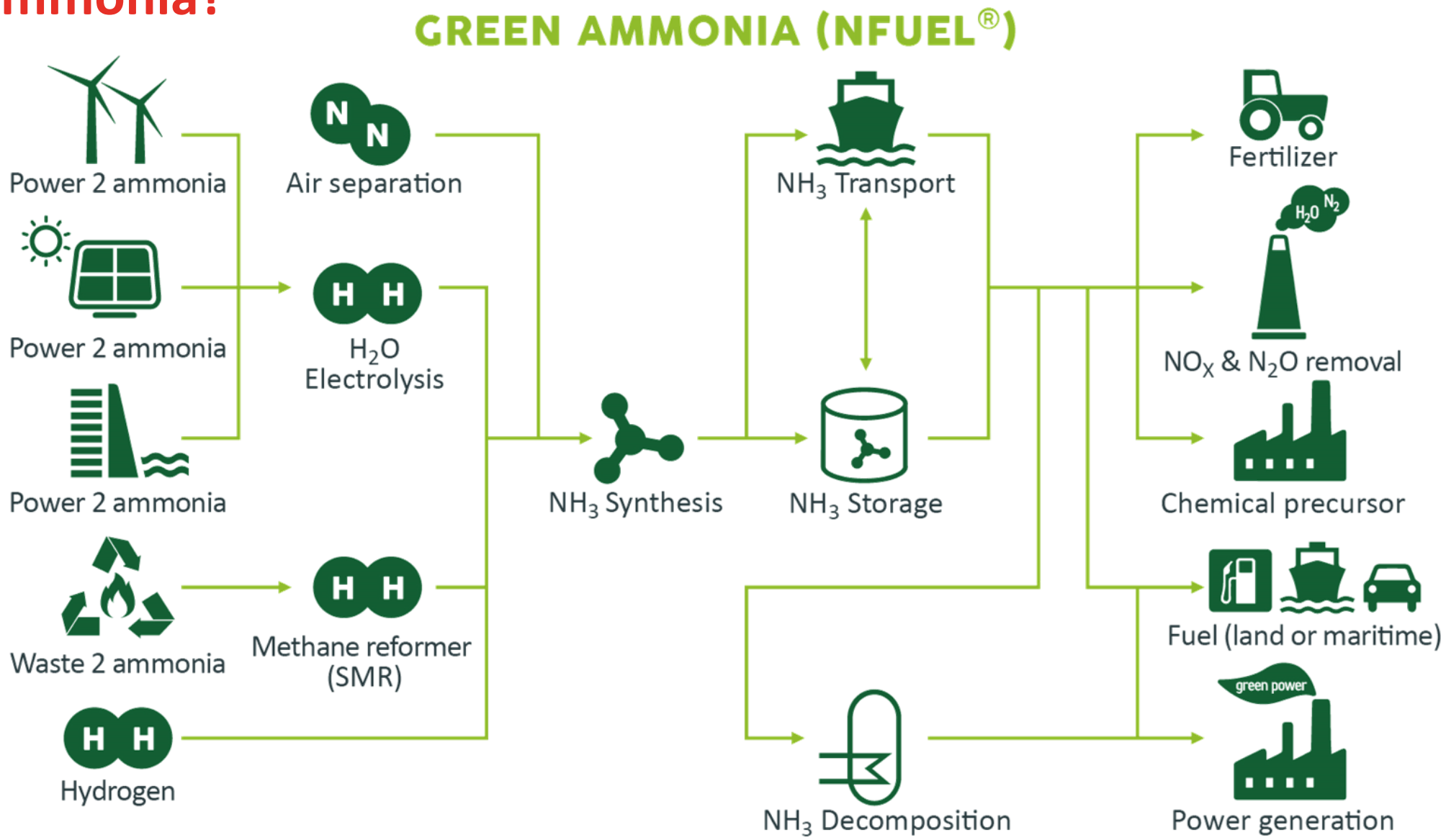
Why Ammonia?



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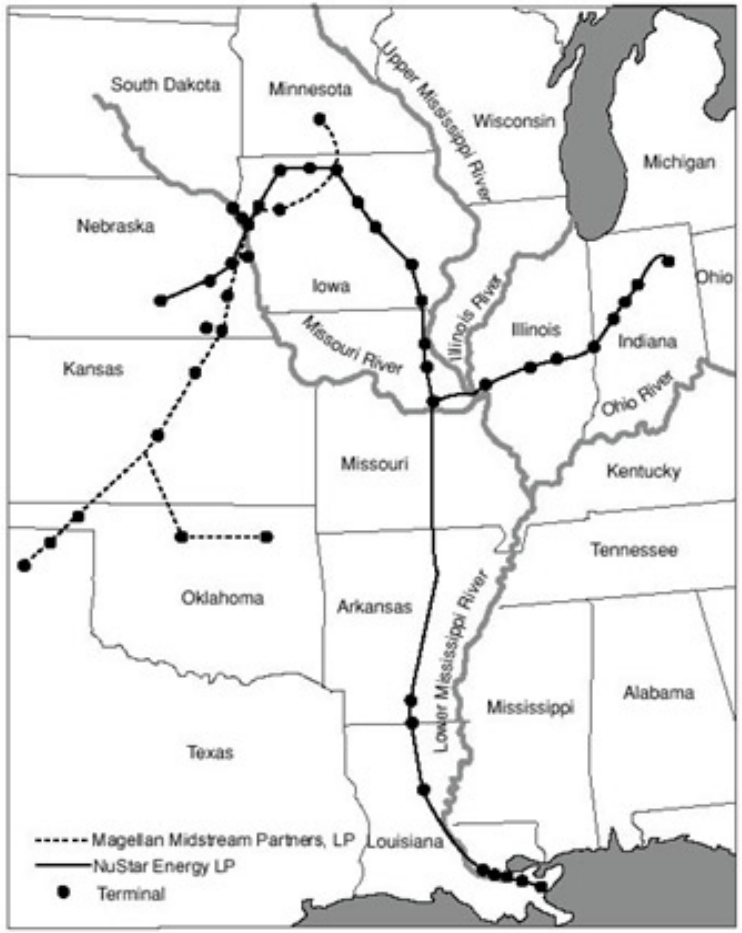
Ammonia storage and transport



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

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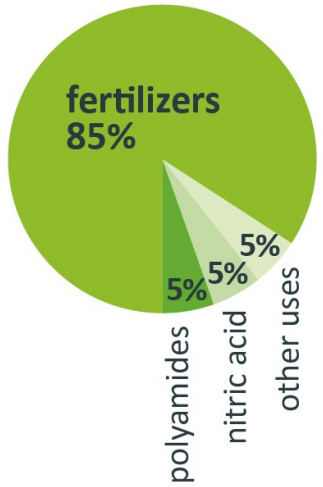
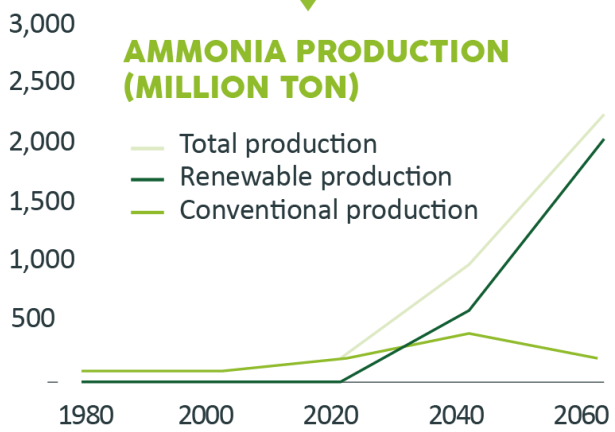
Ammonia applications - conventional & innovative

NITROGEN CARRIER



AMMONIA MARKET



Source: *C-Job, June 2017*

Ammonia innovations

- 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 as hydrogen carrier
- Transhydrogen Alliance announces collaboration to bring green ammonia to Europe

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Ammonia, the ideal hydrogen carrier

- 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.

Storage properties	H_2 (gas)	H_2 (gas)	H_2 (liquid)	NH_3 (Pressurised)	NH_3 (Cooled)
Pressure (bar)	300	700	1	8.6	1
Temperature (°C)	20	20	-253	20	-33
Density (kg/m^3)	23.7	41.6	70.8	611	681.6
H_2 (kg/m^3)	**23.7**	**41.6**	**70.8**	**107.8**	**121**

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NH_3 Event

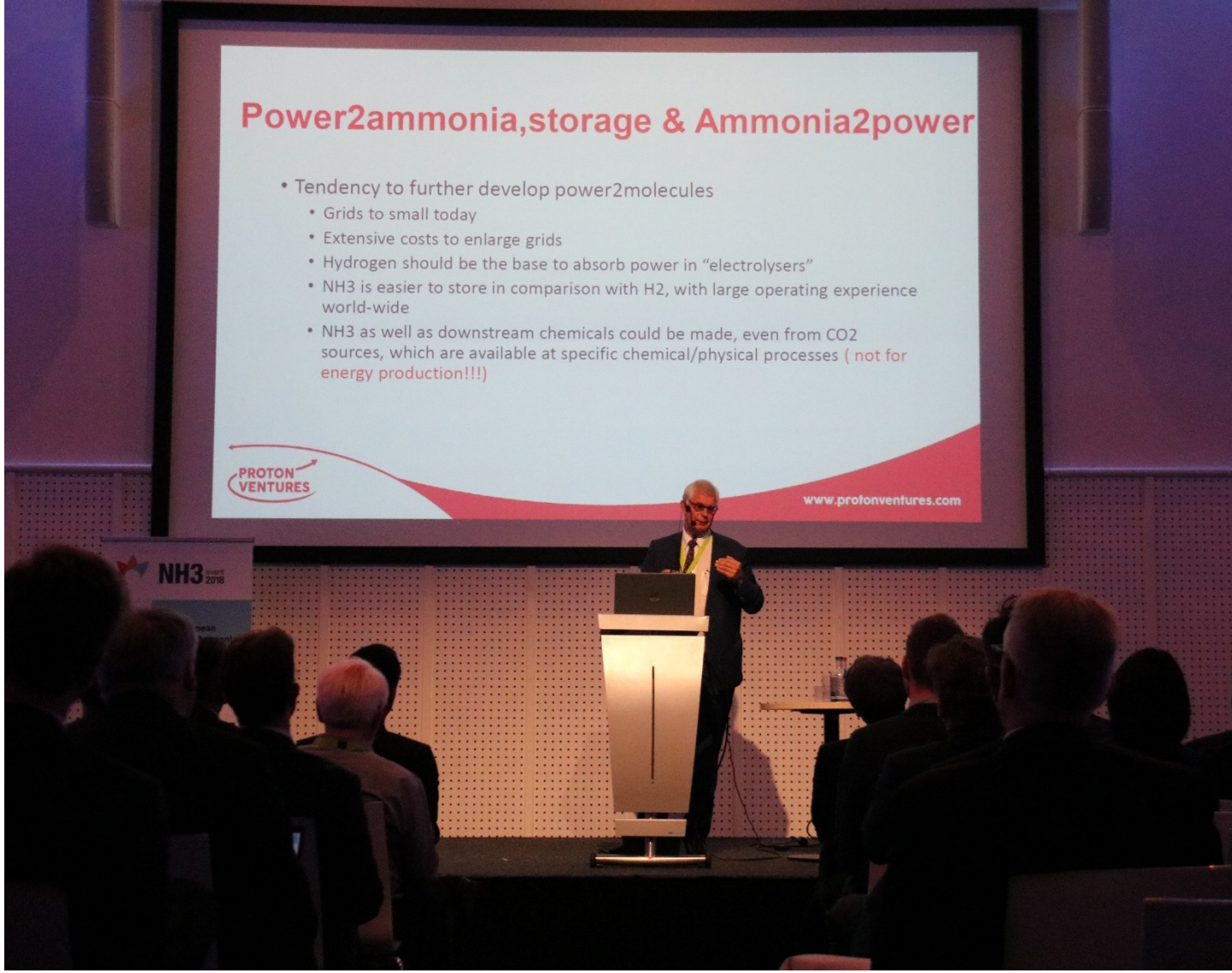
Organiser of the yearly European (green) NH3 event since 2017

> 160 participants

June 3 & 4 2021 – Rotterdam

www.nh3event.com

NH3 event



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About Proton Ventures

EMPOWERING STORAGE SOLUTIONS.

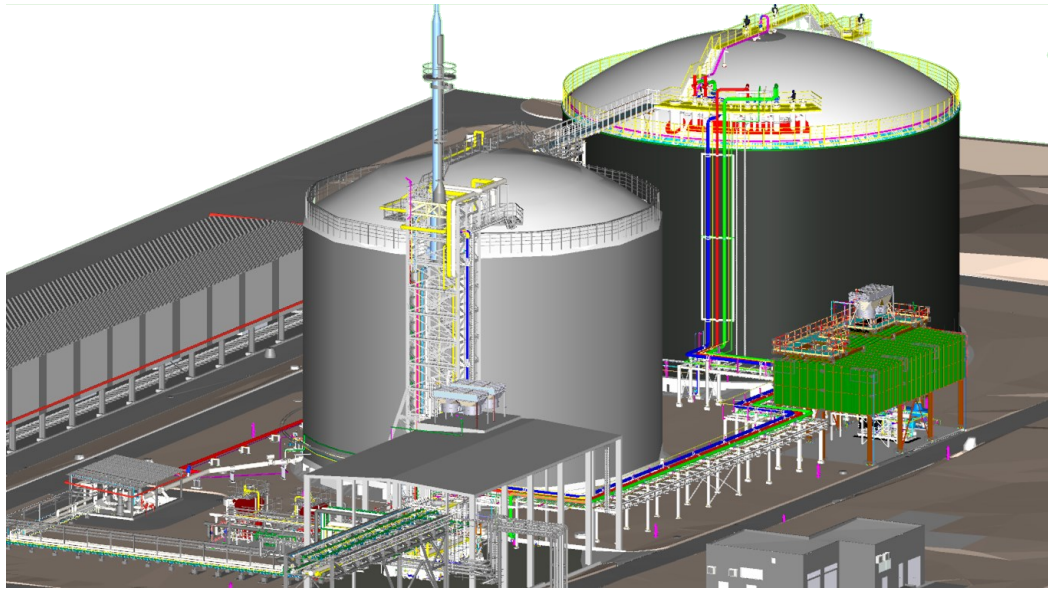
Chemicals, green energy and beyond.

Mission:

We provide innovative engineering and turnkey solutions for world-scale storage terminals, decentralized ammonia production units and other related process applications. We enable our global partners to benefit from our safe, reliable, efficient and environmentally responsible solutions.

Vision:

We strive to be a key player in decentralized chemical energy storage making renewable energy accessible for everybody.



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About Proton Ventures

Proton Ventures is based in **Schiedam** (The Netherlands), with close proximity to the industries within the Port area of Rotterdam

We are a team of 25 enthusiastic professionals who can develop, design and implement customized solutions (EPCM) for our customers.

About Proton Ventures

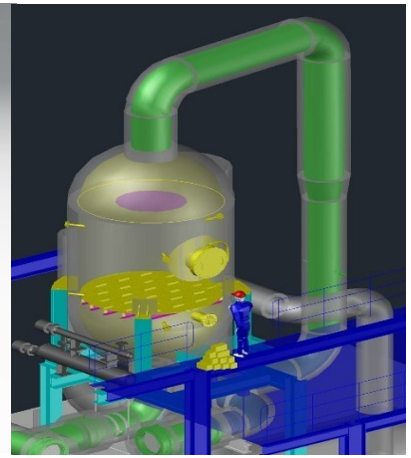
- 35 years experience in ammonia business
- Globally active in ammonia (storage) market, energy (storage) market
- Focusing on modular ammonia production
- Working towards the energy transition from the chemical (ammonia) perspective

Ammonia business segments

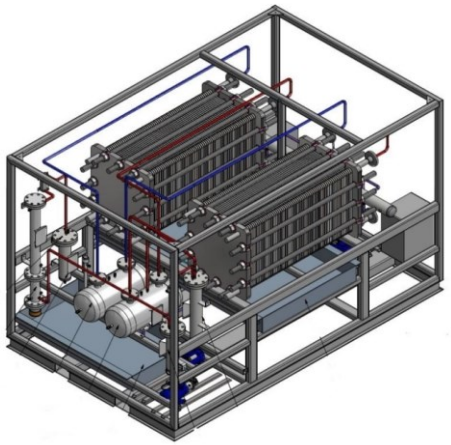
NH_3 storage

NH_3 Production

NO_x & N_2O removal



Battolyser



Ammonia decomposition

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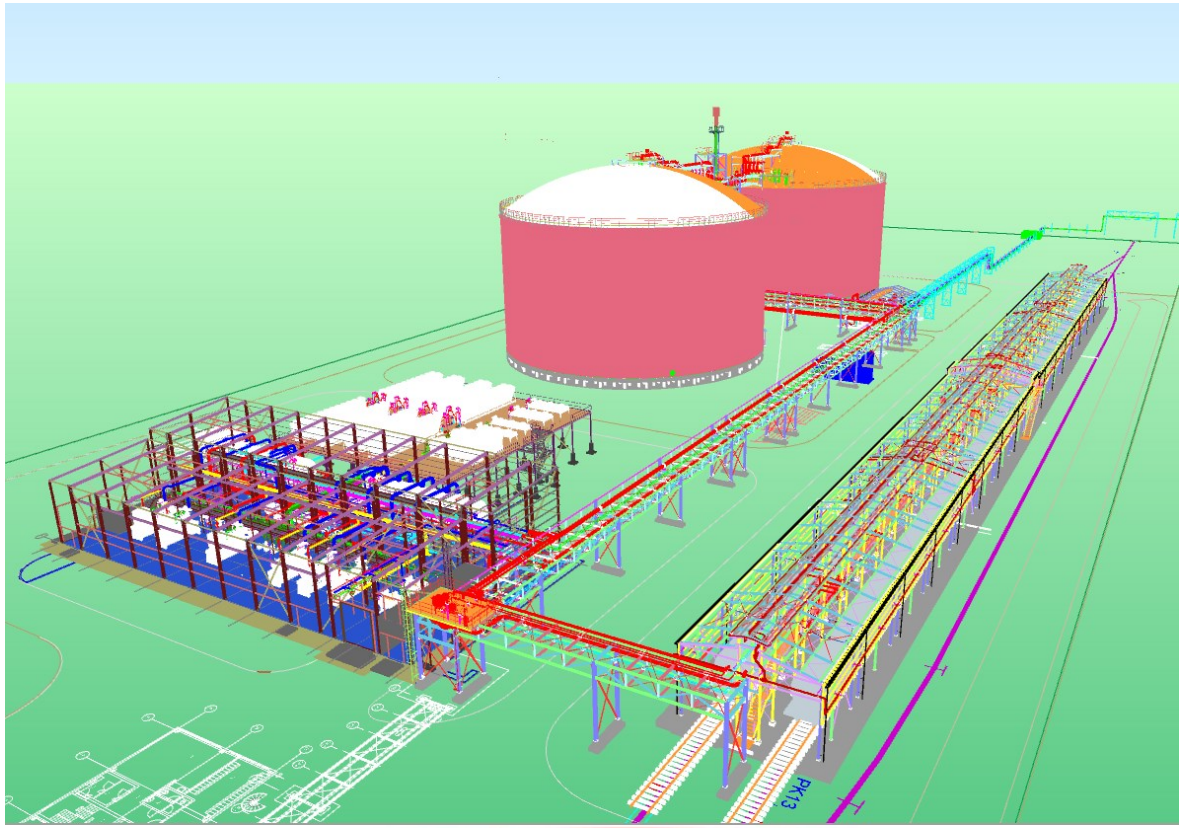
NH_3 (energy) storage & handling

- 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)
- 12.500 Metric ton Bulgaria (2020) (under construction)

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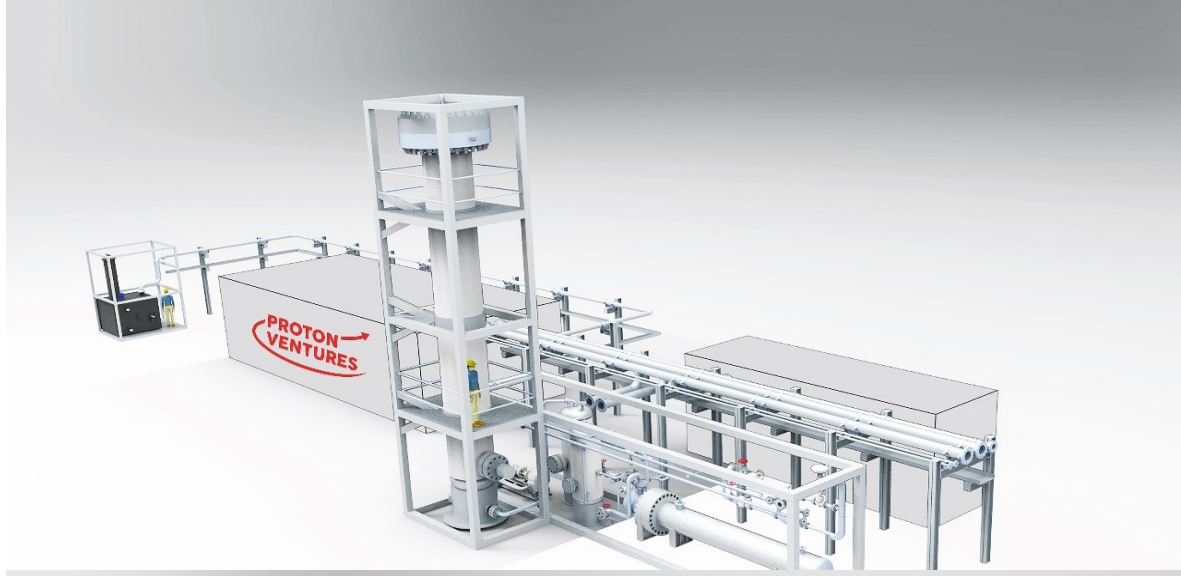
NH_3 production (NFuel® system)

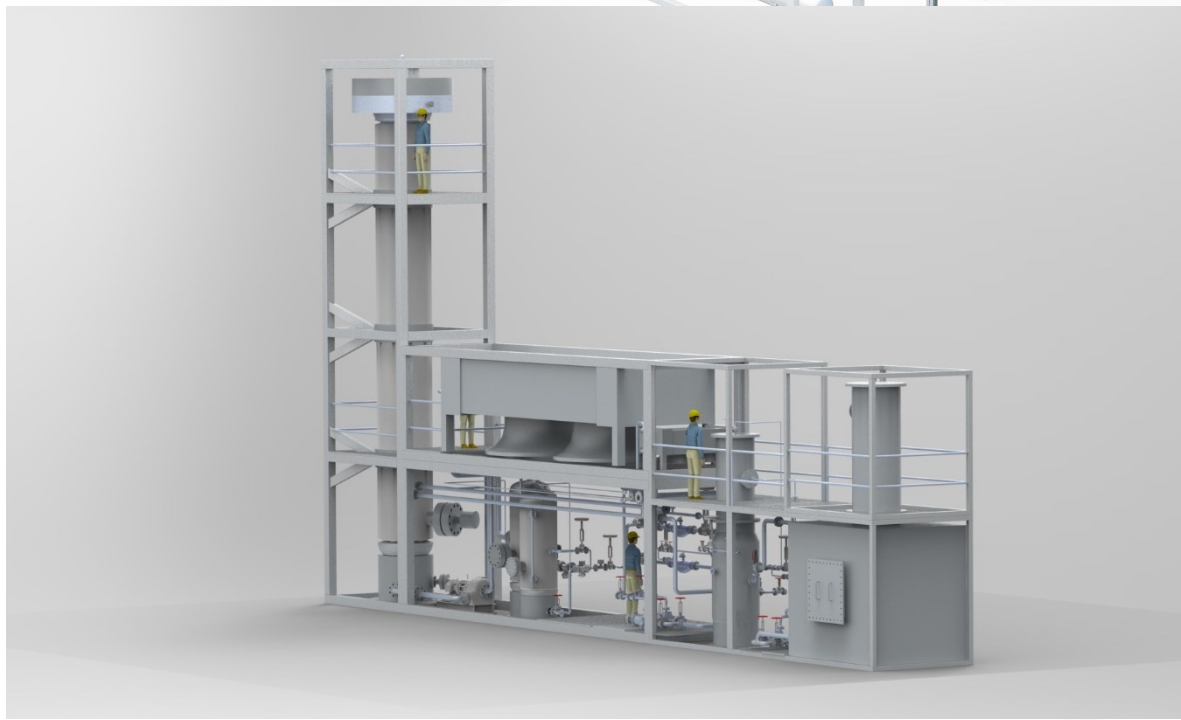
Key features

- Casale licensed Technology

Unit Size	Kg/hr	Metric tons/day	Metric tons/annum
NFUEL® 1	120	3	1.000
NFUEL® 4	415	10	3.650
NFUEL® 20	2.500	48-60	20.000

- Standarised designs for Minimum CapEx & optimised OpEx approach
- Scalable
- Minimum site activities thanks to plug & play designed skids
- Allows fluctuations in feedstock
- Based on existing HB technology (Downscaled)
- Hot-standby of Ammonia reactor (for intermittency purpose)



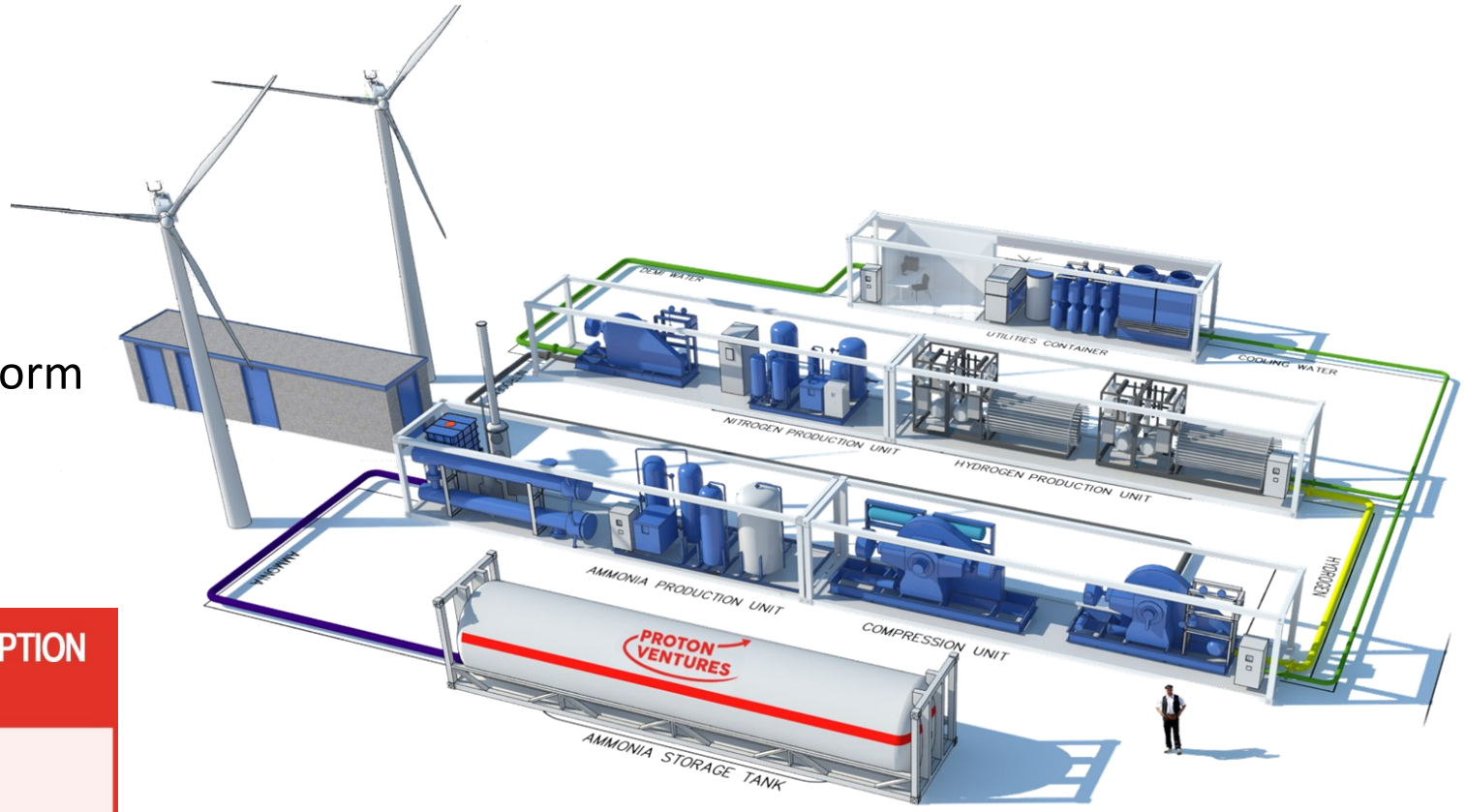


NFuel® Power 2 Ammonia

Power2Ammonia (using Electrolyser)

- Use of stranded electricity
- Storage of energy in liquid form
- CO_2 free economy
- Creating a carbon free fuel
- Efficient hydrogen storage in a liquid form
- For grid stabilisation purposes
- Scalable

UNIT	CAPACITY metric ton/year	CAPACITY metric ton/day	POWER CONSUMPTION Megawatt
NFUEL 1	1000	3	1,5
NFUEL 4	4000	10	5-6
NFUEL 20	20000	60	25-30

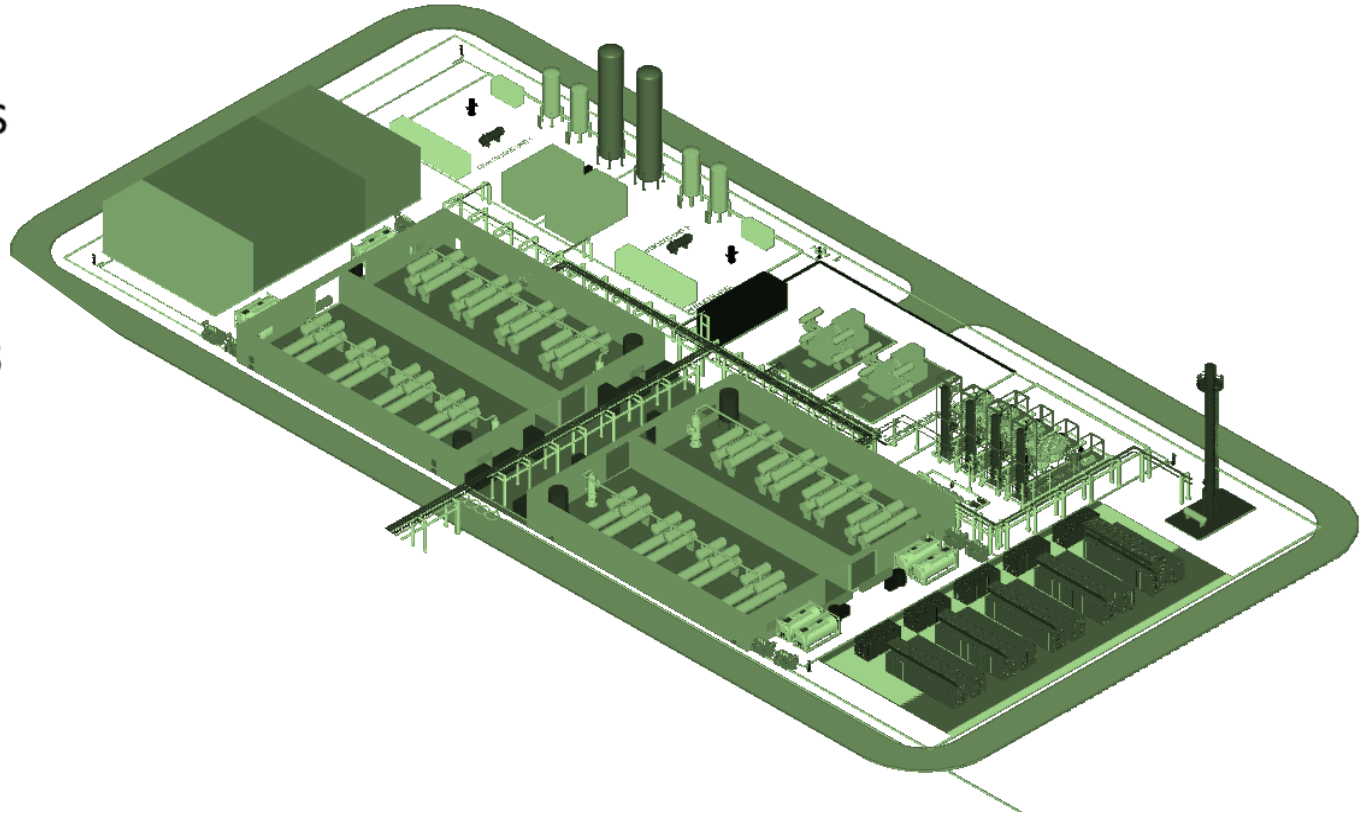


NFuel® Practical experience

#>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



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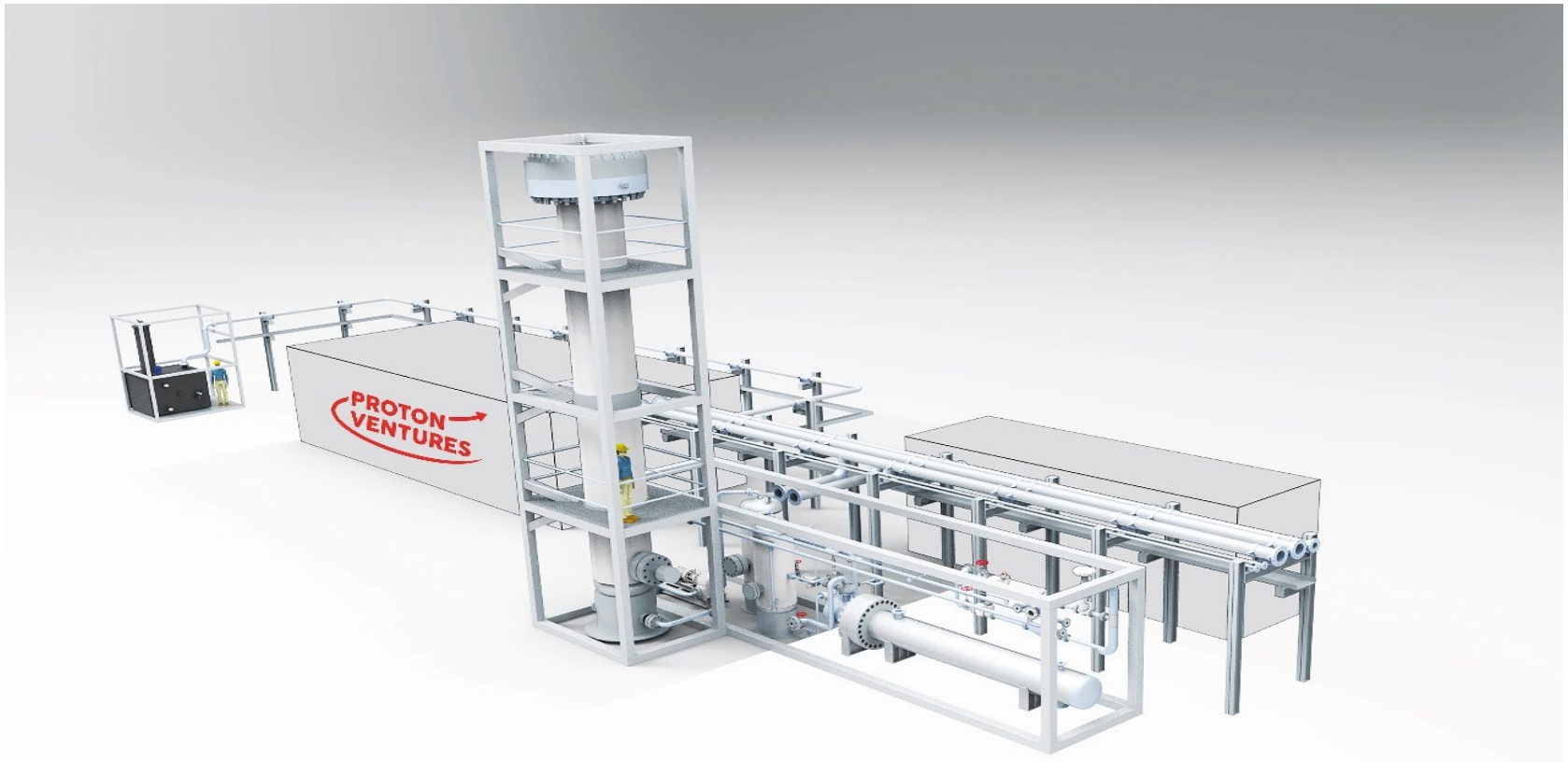
NFuel Practical experience highlights – FEED & BEP NH_3 Plants

- **Front-End Engineering & Design (FEED)** study for a 1,000 ton renewable ammonia plant in close collaboration with Casale S.A. from Switzerland;
- Basic Engineering design (BEP^+) for a NH_3 production facility producing **18,000 ton** of anhydrous ammonia per annum.

Render:
18,000 ton per annum ammonia plant

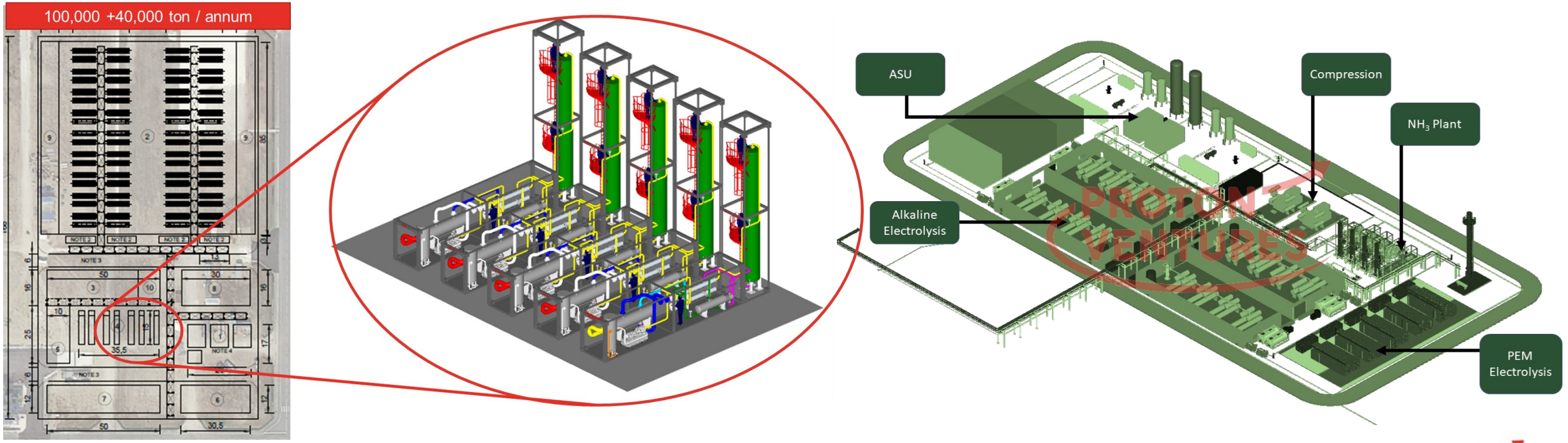
- Make up gas purification unit
- Compression unit
- HB ammonia loop
- Emergency system
- Auxiliary equipment;



NFuel Practical experience highlights – BEP & Feasibility assessments

Proton Ventures:

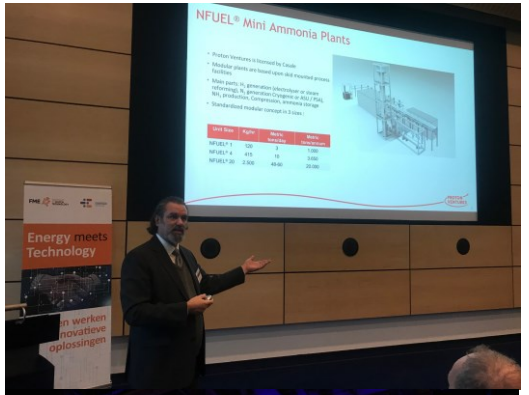
- Performed a **Front-End Engineering & Design (FEED)** study for a **20,000 ton Ammonia Plant** in the USA using natural gas as feedstock;
- Performed various feasibility study for ammonia plants in ranging from 1,000 to 80,000 ton ammonia per annum, for instance the **20,000 ton Electrolysis based (PEM) Green Ammonia Plant** on Goeree Overflakkee.



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. Moreover, 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.



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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**
- Member of the Energy Island Goeree Overflakkee
- 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

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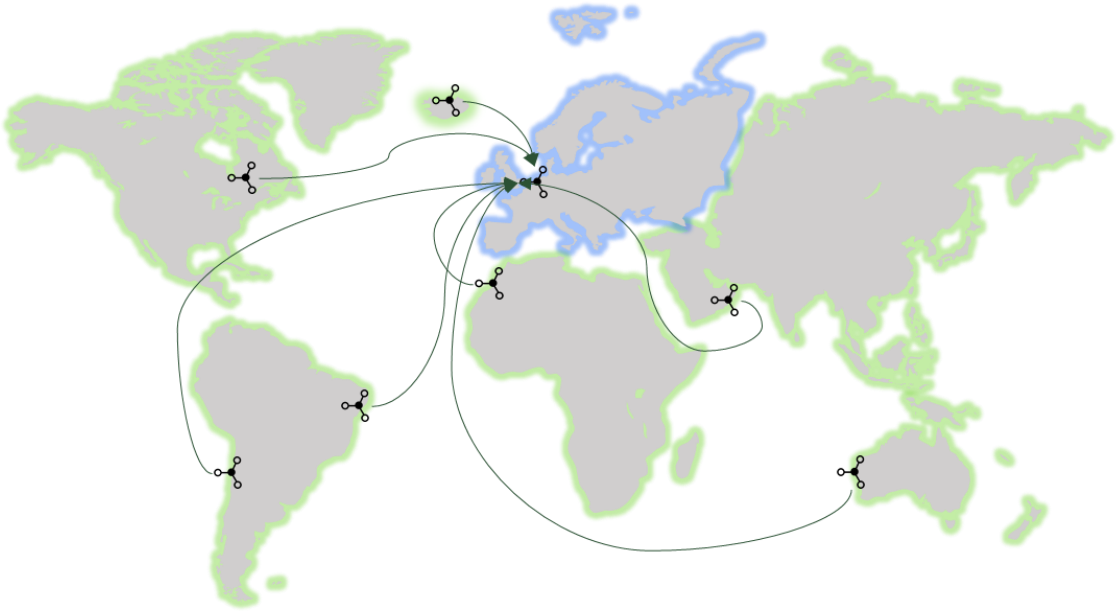
Proton Ventures' Transhydrogen Alliance

Proton Ventures established the **Transhydrogen Alliance**. The alliance wants to work together with specially selected partners in specific countries to create a new export industry and all related benefits. We believe that the alliance includes all the ingredients to kickstart the green Hydrogen/ammonia economy.



Proton Ventures' partners in the Transhydrogen Alliance:

Trammo

Experts in transport and sales and marketing of ammonia & NFuel in existing markets making use of their existing fleet and customer base.

Confidential

Experts in Liquid Storage Solutions & Operations worldwide.

VARO

Oil & Gas experts in distribution and marketing and sales of green fuels in captive markets making use of their existing infrastructure.

Port of Rotterdam

Supporting partner

Offering support and assistance to develop a terminal location in the Port of Rotterdam.

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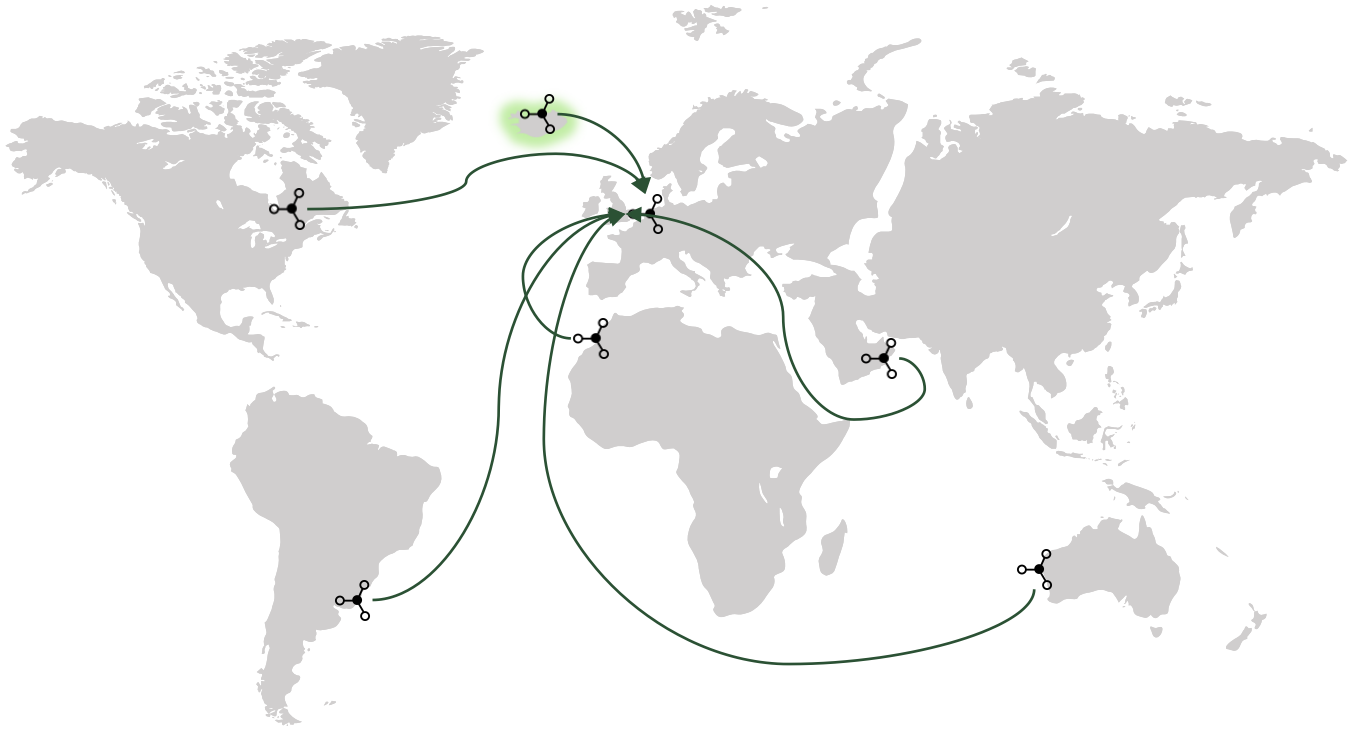
The Objectives / Opportunity

- 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 wants 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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The Transhydrogen Alliance – A complete value chain

The "Transhydrogen Alliance" offers a fully integrated team in the green hydrogen and green ammonia supply chain with knowledge and experience in technology, logistics and sales.

Renewable Power	H_2 Production & Conversion	Local gas distribution	Storage & Export	Transport	Storage Design & operation	Local distribution	Decomposition H_2 or NH_3 sales
RE Park developer & operator	GNH_3 plant operator	Gas transport operator	Export Terminal Operator	Fleet Owner / GNH_3 Trader	Import terminal operator	Gas transport operator	Sales & marketing
Local Partner(s)	PROTON VENTURES	PROTON VENTURES	*Confidential* PROTON VENTURES	Trammo	*Confidential* PROTON VENTURES Port of Rotterdam	VARO Port of Rotterdam	Trammo VARO

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The Project: A two stage approach

1

Demonstration phase

- Small scale unit(s) allowing for 40,000 to 60,000 metric ton per year of green ammonia production
- Timeline for demonstration facilities deployment is 2022 - 2023
- Allows for gradual expansion in case allocated land is available and permits for expansion are arranged.

2

Commercialization phase

- Multiple larger units of 20,000 ton per year production capacity or more will be deployed in the years 2023 – 2026 up to an overall total of 1,000,000 metric ton per annum production capacity.
- Allows for lowering overall costs across the supply chain resulting in lower price for the green ammonia.
- Client / of taker is owner of the facilities.
- In this phase the Consortium acts as an EPC contractor

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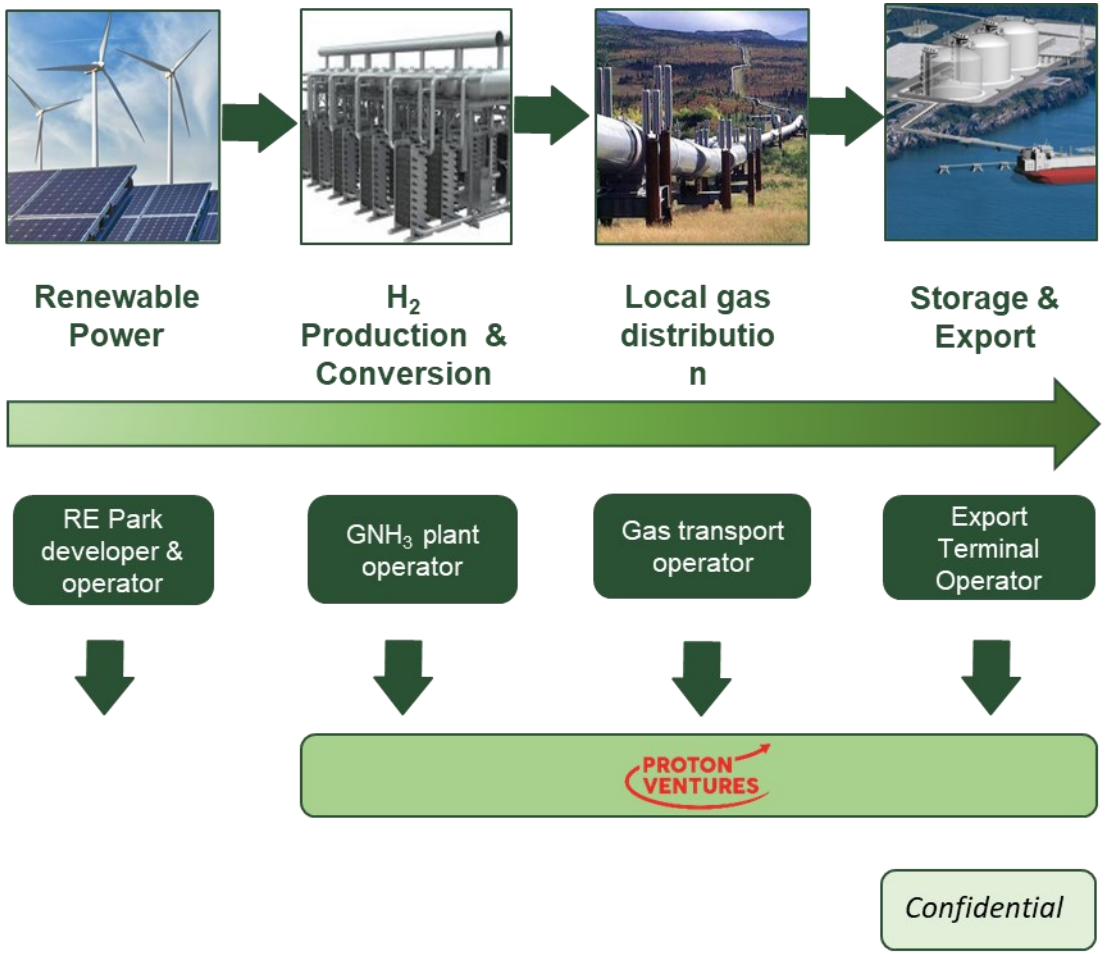
Local partners, how can we cooperate?

The THA consortium will enable:

- Your country to become one of the first movers of green hydrogen production, with a potential for export
- The development of a new export industry with related financial and job benefits
- Build up a local skill set and knowledge industry
- Possible development of related equipment industry

Local Stakeholder support is being investigated for:

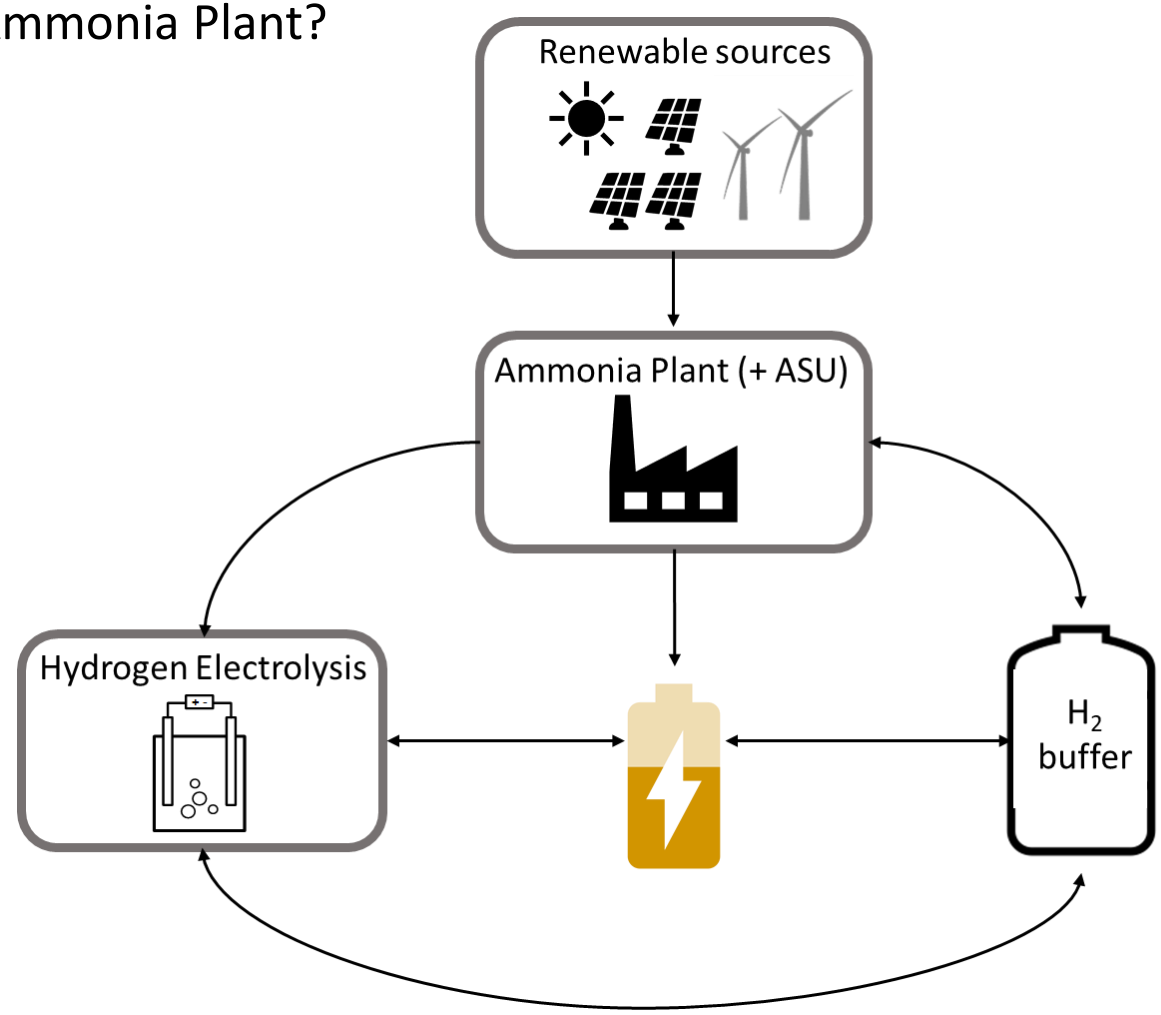
- Provision of renewable energy, where? By whom?
- Provision of land for RE, conversion facilities, export terminal
- Connection between RE park and port
- Provision of demineralized water
- Local support to operation the plant
- Local ammonia distribution
- Local support to operations of export terminal
- Investor in local assets
- Local subcontracting support (for assembly & construction)



Technical challenges

How to integrate Renewable Energy to an Green Ammonia Plant?

- Capacity Factor RE
- Required Flexibility
- Optimised hydrogen production
- Ammonia Plant Capacity
- Hydrogen and electricity storage
- Storage
- Distribution
- Etc..



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Alternative Routes for 2670 ton H2 transport per ship

NFuel (**GREEN Ammonia**) — **2670 ton H2**

- **3 H_2** + N_2 => 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. 25% of initial H_2 quantity (***Why do this and not use directly the NH_3?)***
- 15,000 ton NH_3 requires some **22,500 m^3** storage volume on ship

LOHC (Liquid Organic Hydrogen Carrier) — **2670 ton H2**

- 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
- 45,000 ton LOHC requires some **58,500 m^3** storage volume on ship

LH_2 — **2670 ton H2**

- Liquid at -253 °C, requiring some 3.9 (theoretical minimum) up to 16 kWh/kg H_2 in energy (12 - 50% of energy value is lost)
- 2,670 ton **liquid** H_2 requires some **38,000 m^3** storage volume on ship
- Compressed H_2 **gas** at 200 barg would require for the same 2,670 ton of **22,000,000 m^3** storage volume on ship

CH_4 – CH_3OH (MeOH) — **2670 ton H2**

- The formation reaction requires CO_2 and generates consumes H_2 due to H_2O being formed
- **4 H2** + CO2 ➔ 1 CH4 + **2 H2O** (loss is 50% in H2) Equals **200% Capex** for solar or wind compared to NFuel/LOHC
- **3 H2** + CO2 ➔ 1 CH3OH + **1 H2O** (loss is 33% in H2) Equals **150% Capex** for solar or wind compared to NFuel/LOHC
- But lower transport costs! But also no CO2 available cheap in solar or wind rich areas

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Contact Details

Proton Ventures

www.protonventures.com

NH_3 event

www.nh3event.com

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