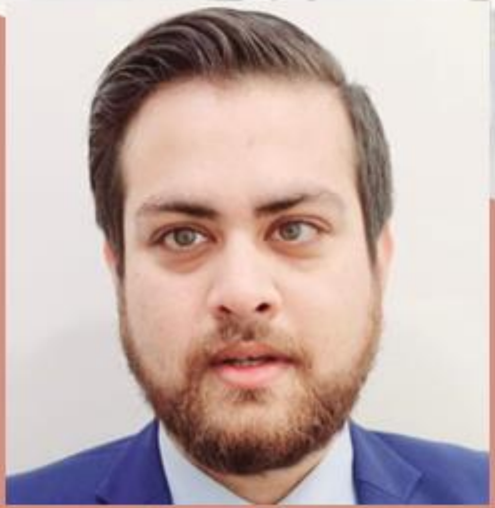
WEBINAR

Ammonia Project Features

(Monday 20 March, 4PM IST, online via Zoom Webinar)

India: seizing the renewable opportunity



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Leading Through Innovation

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In conversation with:

Kevin Rouwenhorst
Technology Manager, AEA

AMMONIA ENERGY ASSOCIATION

Ammonia Project Features

(Tuesday 25 April, 4PM CET, online via Zoom Webinar)

Using surplus hydroelectricity for ammonia production in Paraguay

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CEO, ATOME

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CTO, Casale

Santiago Del Valle
MD, URBAS Energy-Ingeser

In conversation with:

Kevin Rouwenhorst
Technology Manager, AEA

AMMONIA ENERGY ASSOCIATION

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OMAN GREEN AMMONIA PROJECT SHOWCASE

World Hydrogen MENA

Dubai (Mar-23)

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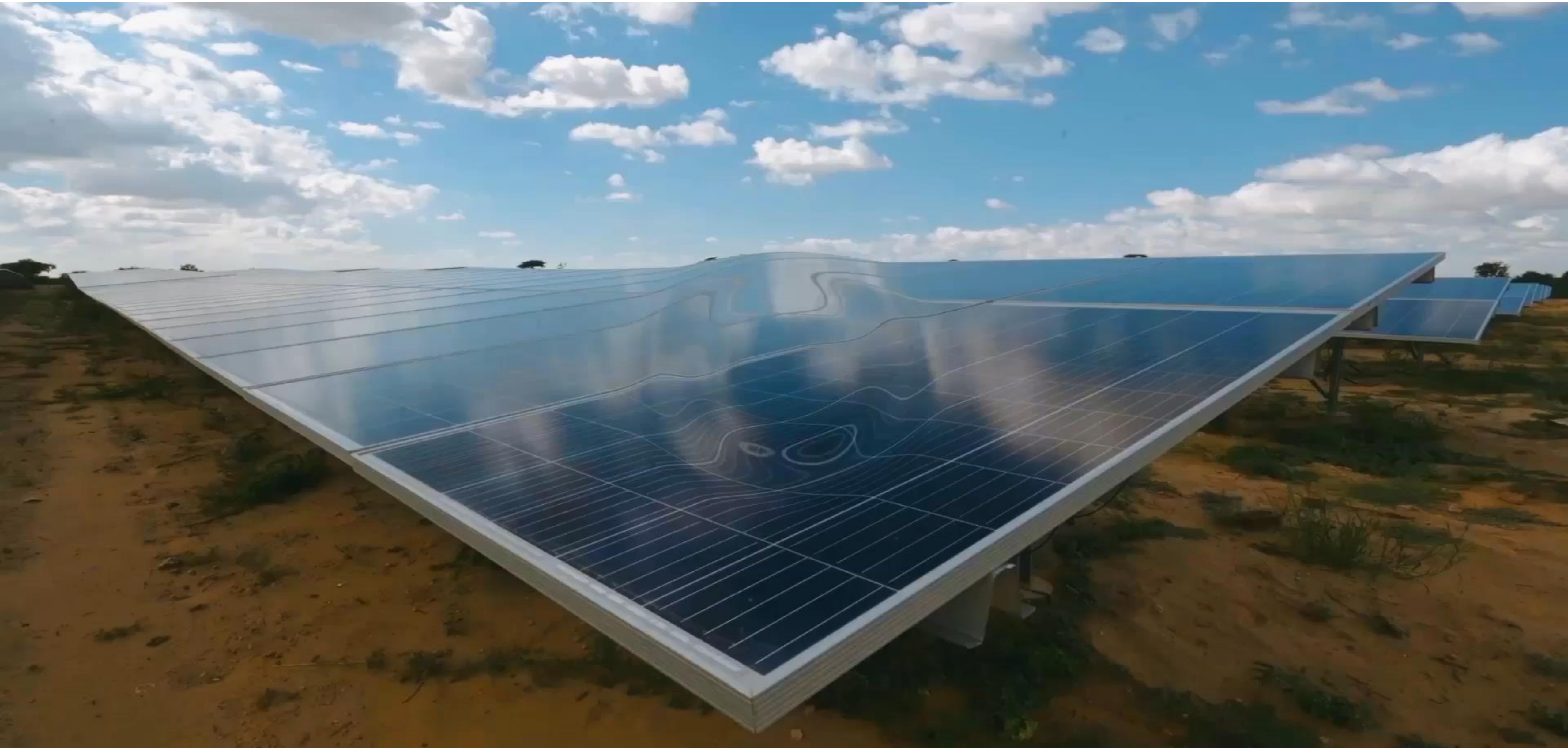
ACME Group – a history of Disruption in Telecom & Energy industry

Period	2003-2009: **Telecom Infra**	2010-Present: **Solar Business**	2020-Present: **Green Fuel**
Disruption	✓ Invented fit for market products in telecom passive infrastructure space including Power Interface Unit (PIU) and Phase Change Material (PCM)	✓ India's first IPP to achieve , build and operationalize a solar power plant with subsidy free tariff of INR 2.44 INR/kWh (~3 cents/kWh)	✓ Commissioned World's first Green Hydrogen and Green Ammonia in Bikaner, Rajasthan
Impact	✓ Up to 70% reduction in telecom tariffs on account of energy savings contributing to lowering calling rates from $0.20/minute to $0.07/minute	✓ ACME's $0.03/kWh tariff broke the grid parity barrier for renewable power making it cheaper compared to average cost of thermal power by around 25% and accelerated adoption in solar power in India with 60 GW of present capacity and another 100 GW under-development	✓ Proof of concept as allowed for regulatory and policy push for adoption of Green Ammonia/Hydrogen in India ✓ Execution experience enabling optimisation of design and operations for large scale Green Ammonia/Hydrogen plants

Vision	Top 3 Green Energy producers in the World, producing 10 MTPA of Green NH3/ H2 by 2030

Bikaner: World's first integrated Solar Power, Hydrogen & Green Ammonia plant

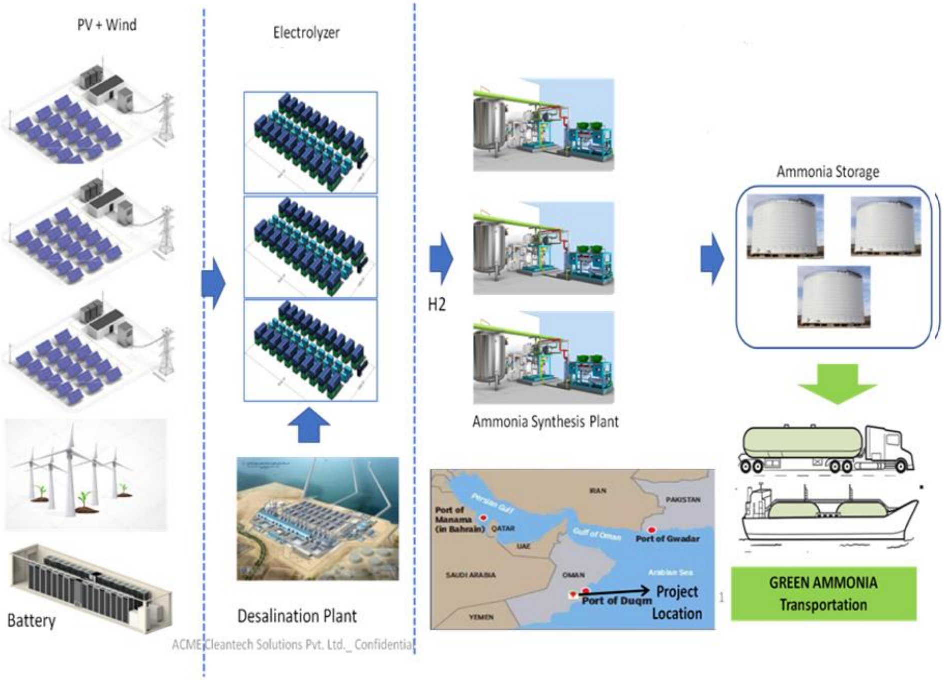


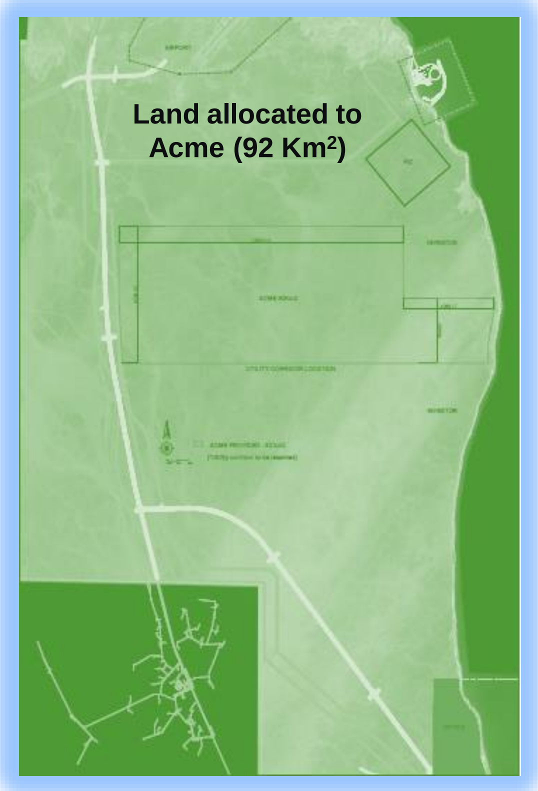
Oman Project: First commercial scale project

ACME is developing one of the World's earliest Green Ammonia project in port of Duqm, Oman

- ✓ Land Acquired- Usufruct Signed
- ✓ Statutory approvals in place
- ✓ Off-take Term sheet Signed, Agreement in Final Stage
- ✓ Ammonia Technology Order Placed
- ✓ Jetty Order Placed
- ✓ Ammonia Storage Tank Order Placed
- ✓ ESIA approved
- ✓ Construction permit granted
- ✓ FC expected: Mar-23
- ✓ COD: Dec'24 – Jun'25

Green NH3 – ~ 1.2 MTPA (Phase 1 and 2) | Investment – USD 6 billion





Key Partners

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OMAN Project - First-ever Green Ammonia Certificate

Green Certificate

CERTIFICATE

Certificate-ID:	C01-2022-03-21255363
Applied Standard/Criteria:	TÜV Rheinland Standard H2.21 for Green Hydrogen, and Carbon neutral processing to Green Ammonia
Certificate Holder:	Green Hydrogen & Chemicals SPC The Special Economic Zone Duqm Al-Duqm Al Wusta Governorate 111 Oman
Certificate valid until:	31.03.2023

Production of Green Hydrogen and Green Ammonia

TÜV Rheinland confirms that the holder of this certificate is planning, as a Greenfield Project, a PV powered hydrogen-ammonia plant that meets all criteria for the production of Green Hydrogen as an intermedia product, as well as Green Ammonia as the final product.

The following criteria have been assessed as fulfilled for the entire Greenfield Project:

- Electrolysis for hydrogen production is planned to be exclusively powered by electricity generated from an affiliated PV plant, as renewable electricity source.
- The hydrogen is further synthesized to ammonia via Haber Bosch process in a carbon neutral way.
- During daylight hours, surplus electricity of the PV plant will be fed into the grid for banking purposes. Its amount will be higher than the power consumption needed for the entire plant during night times, also considering transmission and distribution losses (conservative approach).
- The technical setup of the project plant maintains carbon neutrality of hydrogen and ammonia in their boundaries cradle to gate. Since renewable electricity for electrolysis is applied, the products can additionally be declared as Green Hydrogen and Green Ammonia.

Cologne, 01.03.2022

Norbert Heidelmann
TÜV Rheinland Group
Carbon Services

Daniel Gersdorf
TÜV Rheinland Group
Carbon Services

TÜVRheinland®
Genau. Richtig.

Through its project in Duqm, ACME Company receives the world's first accredited international certificate for commercial clean hydrogen production

The Public Authority for Special Economic Zones and Free Zones (OPAZ)

commended the announcement of ACME, a leading company in the renewable energy sector for receiving the first-ever international certificate accredited for commercial production of green hydrogen and ammonia in the world

through its project in Duqm. The company obtained this certificate from

the German technical services company TUV Rheinland.

عُمـــــان .. نبنيهـــا معـــا
Building Oman Together

الهيئة العامة للمناطق الاقتصادية الخاصة والمناطق الحرة
Public Authority for Special Economic Zones and Free Zones
Sultanate of Oman سلطنة عمان

SPV of Acme Group

ACME has been issued world's first Green Ammonia Certificate by TUV Rheinland, Germany

Oman Project: Work at Site – progress photos

Labour Camp Overview at Site

Kitchen block & Water Tank

Site office Installation

Underground work & plumbing under progress

Green Ammonia Projects Pipeline

Tamil Nadu

Project Capacity – 1.1 MTPA

- MoU signed in July 2022
- The project will be set up at the port town of Thoothukudi
- The project will comprise 5,000 mw of solar PV plant, 1.5 GW of the electrolyzer and 1.1 million tons of ammonia synthesis loop

✓ Government Benefits and Grants
✓ Land Identified, due diligence in progress
✓ Under development

Odisha

Project Capacity – 1.1 MTPA

- MoU signed in December 2022
- Proposed to set up near to Paradeep Port

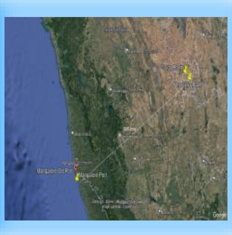
✓ Government Benefits and Grants in progress
✓ Land Identified, due diligence in progress
✓ Under feasibility

Karnataka

Project Capacity – 1.1 MTPA

- MoU signed in June 2022
- To set up a 1.2 mtpa Green Hydrogen & Green Ammonia project.

✓ MOU Signed
✓ Land Identified, due diligence in progress
✓ Under feasibility



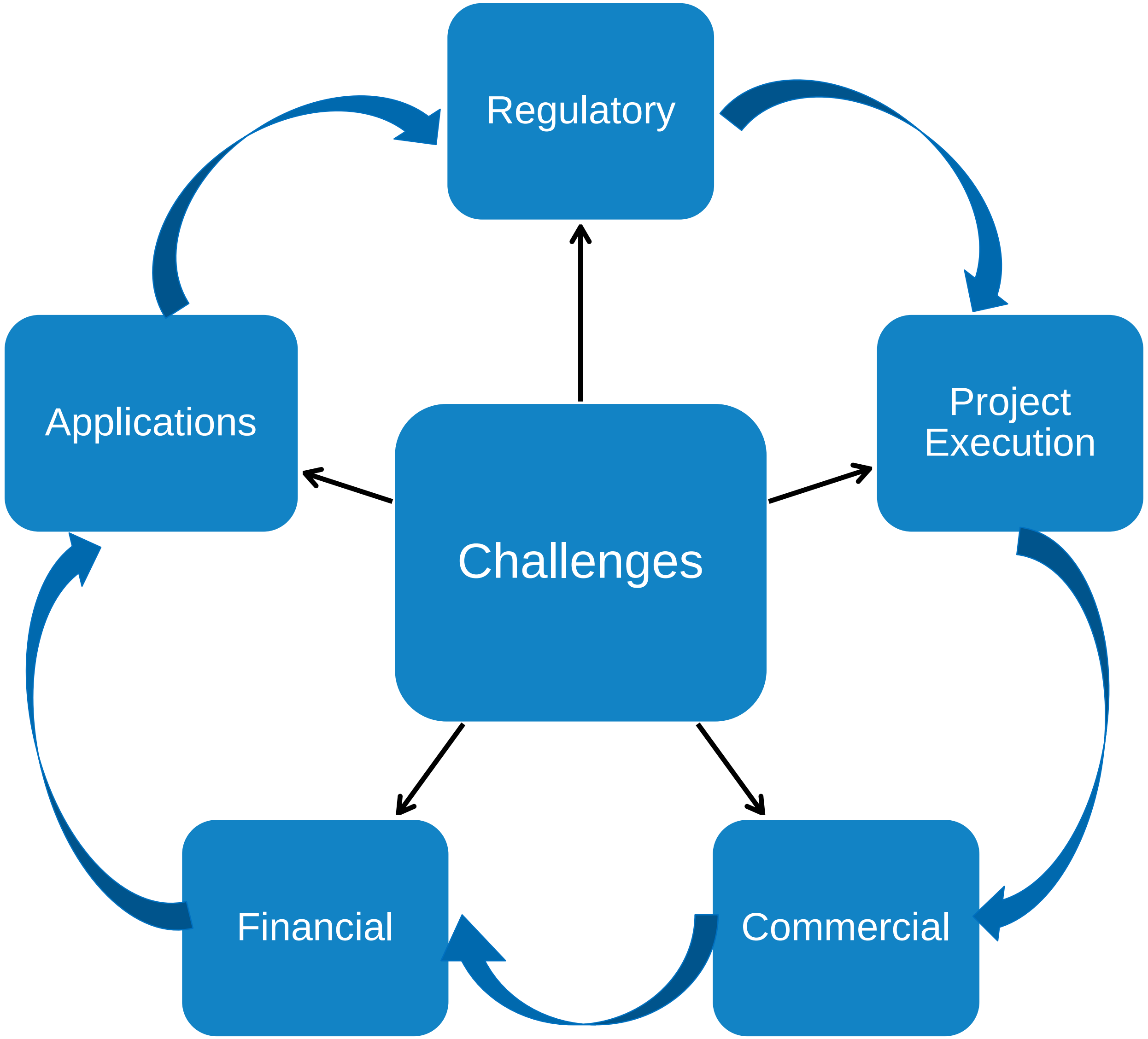
Egypt

Project Capacity – 2.1 MTPA

- MoU Signed in August 2022
- Total production capacity: up to 2.1 mtpa of Green Ammonia at Ain Sokhna, Egypt

✓ MOU Signed
✓ Land Identified, due diligence in progress
✓ Under feasibility

Challenges in Developing a Green Ammonia project



Regulatory Challenges

- Non – Uniformity of Green Product Specification
- Tradability for cross border trade

Project Challenges

- Availability of resources (Land, Water & Firm Power)
- Storage and Logistics

Commercial Challenges

- Benchmark Pricing of Green Ammonia
- Commercial terms
- Competition with Blue / Grey Products

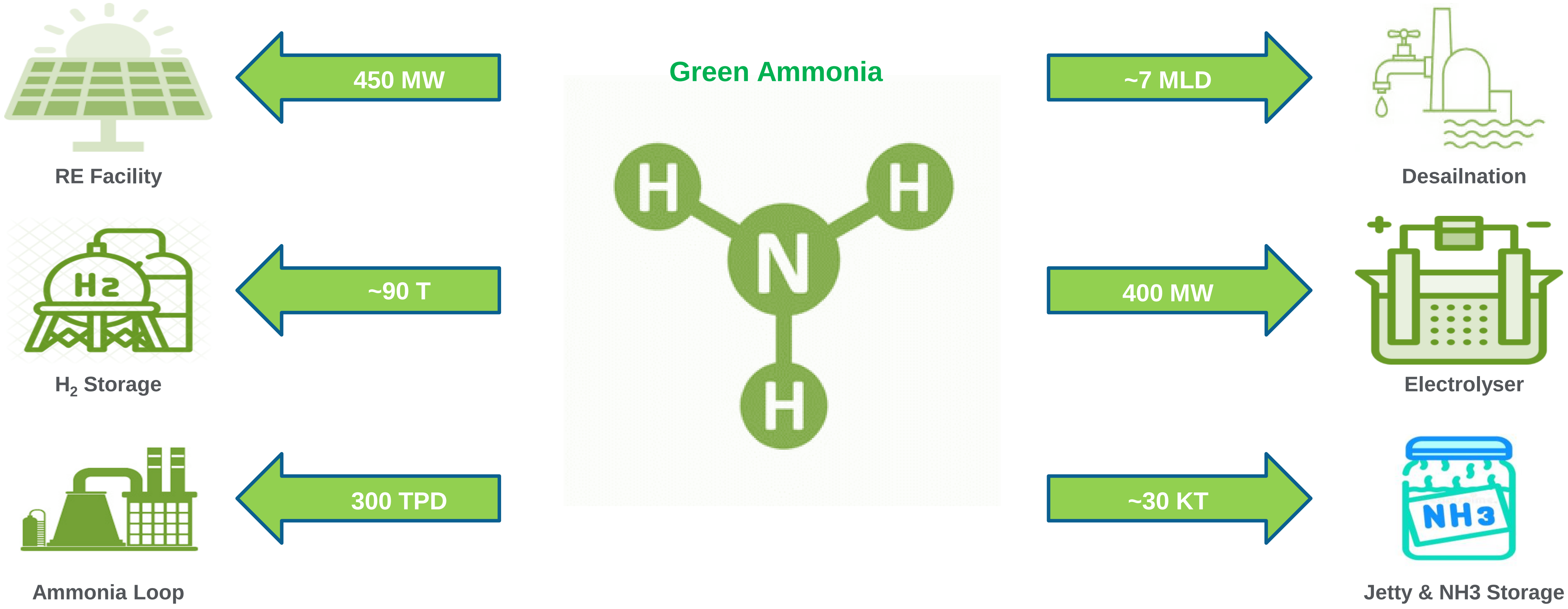
Financial Challenges

- Lender's perception to the new Sector
- Long term offtake, Buyer's rating and Bankability

End Use Applications Challenges

- Existing - Price Sensitivity and Premium w.r.t conventional products
- New. - Development of Retrofitting technologies

Typical Project Configuration [300 TPD of Green Ammonia]



The Facility will be 100% RED (II) / (III) complaint and electrolysers will be powered **exclusively** by RE Power under '**Direct Connection**'. The electrolyser capacity is planned in a way that, apart from feeding the ammonia loop, excess hydrogen will be stored during solar hours and will be utilized for ammonia production during non-solar hours. Ammonia storage will be designed to optimize the transportation and logistics cost

Regulations - What are Green Fuels? EU Criteria for RFBNO….1

Standard Emission (Fossil Fuel Comparator)
94 gCO_{2eq} / MJ

Emissions to be measured from the point of **Production** to the point of **Consumption**

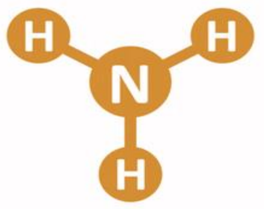
Considering the LHV of Ammonia as 18.80 MJ/kg; Max Carbon Footprint of NH_3
0.53 kg CO_{2eq} / kg

Minimum Reduction – 70%

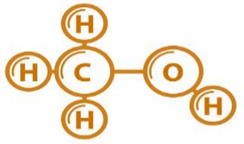
Parameter	Unit	Case I	Case II
Plant (Block) Size	TPD	300	
Base Load (Ammonia Loop and Auxiliaries having 24x7 Operation)	MW	~14	
Annual Energy Demand from Base Load during non-solar hours	MU	~30	~15
CO_2 Intensity of Gas based Generation	kg/kWh	0.79	
Annual CO_2 (indirect: Grid Energy) emissions from NH_3 Production Process	MT	23,700	11,850
Annual Production of NH_3	MT	100,000	
Carbon Footprint (Intensity) of NH_3	MT CO_{2eq} / MT NH_3	0.237	0.118

Potential Green Fuels

Hydrogen



Ammonia



Methanol

Cellulosic

E-Methanol

Case I: Grid supplies 50% Green Power out of total power supplied during non-solar hours; Case II: Grid supplies 25% Green Power out of total power supplied during non-solar hours

End Use Applications – OEM’s dilemma on potential Green Fuels

Regulations - What are Green Fuels? EU Criteria for RFBNO….2

Renewability

- As a principle, liquid and gaseous fuels of non-biological origin are considered renewable when the hydrogen or Intermediatory Product component is produced in an electrolyser that uses with renewable electricity.
- This renewable electricity may be supplied by an installation that is directly connected to the installation that produces renewable liquid and gaseous transport fuels of non-biological origin or may come from the grid.

Additionality [Applicable from 01.01.2027]

- The installation generating renewable electricity should have come into operation not earlier than 36 months before the installation of producing RFBNO

Temporal Correlation

- RFNBO should be produced during the same calendar month Quarter as the renewable electricity [till 31.12.2026 31.12.2029]
- RFNBO should be produced during the same one-hour period [Month / Quarter / Year – as decided by the Commission] as the renewable electricity [From 01.01.2027 01.01.2030]

Geographical Correlation

- Installation producing Renewable Energy is located in the same bidding zone Country as the electrolyser
- In a neighboring bidding zone Country and electricity prices in the relevant time period on the day-ahead market in the neighboring bidding zone is equal or higher than in the bidding zone where the RFBNO is produced
- The installation generating renewable energy is located in an offshore bidding zone adjacent to the bidding zone where the electrolyser is located

Note: **Bidding Zone** means the largest geographical area within which market participant are able to exchange energy without capacity allocation

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Financial Challenge – Lender's perspective

In order to attract private investment and assure cashflow to lender for large scale projects, the necessary potential offtake commercial terms will have following features:

Element	Description	Lender's Requirement / Comments
Buyer's Creditworthiness	*Offtake Contract (Parent Company v/s Subsidiary)*	*Lender's requirement with Buyer having a rating of at least [BBB+ or as per lender's requirement]*
Payment Security Mechanism	*Buyer guarantee (Corporate or Bank)*	*Buyer's guarantee to provide the necessary payment security to the lender*
Portfolio of Buyer's	*Exclusive Offtaker v/s Number of Buyers*	*Given uncertainty in a nascent market, lenders prefer fixing the offtake agreement for the tenor of the debt & agreeing 100% offtake.*
Contract period	*Long term contracts*	*Buyers prefer short-term and Lenders prefer Longer term contract for certainty of cash flows*

Commercial Challenges - Terms

Buyers and Producers have conflicting objectives and there are no guiderails unlike other commodities where contracts are standardized

Element	Description	Comments
Volume Adjustments	*Provision to make necessary adjustment on Annual contracted quantity*	*Agreed Base Annual Contracted Quantity (BACQ) subject to the adjustments due to:* • *Variation in Solar irradiation, Maintenance* • *Round up/down due to Vessel capacity* • *Additional Quantities Produced (if any)*
Force Majeure	*Covering unforeseen situations*	*No international best practices – combination of RE power and conventional Fuels*
Certifications – Green Attributes	*Compliant to RED II/III directives (70% GHG Emission reduction from 94g of CO2/MJ of the Fuel)*	*Green requirement as per RED II/III directive to include compliance to Renewability, Additionality, Temporal correlation, GHG emission reduction*
Take or Pay & Supply or Pay Obligations	*Buyer has an obligation to purchase and pay for the available annual contract quantity (Supply or Pay obligation for the Seller)*	*Given the nascent nature of the green ammonia market, suggested pricing and take or pay obligation will justifiably be required for the project to be bankable and lower project owner's risk*

ACME

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Thank you

India’s Green Ammonia Opportunity

Ammonia Energy Association Webinar
20th March 2023

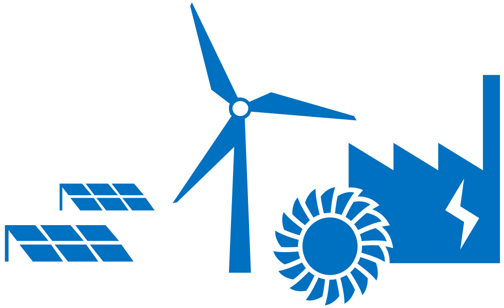
Dr Richard Nayak-Luke
r.nayak-luke@ucl.ac.uk

UNIVERSITY OF OXFORD
UCL

20th March 2023

India’s Green Ammonia Opportunity

1. Context
2. **Supply: Where and how?**
3. Demand: Fertiliser, Shipping Fuel, Energy Vector
4. Conclusion



India is a key market for nitrogenous fertilizer, but due to comparatively small gas resources has dependence on import of nat. gas and products

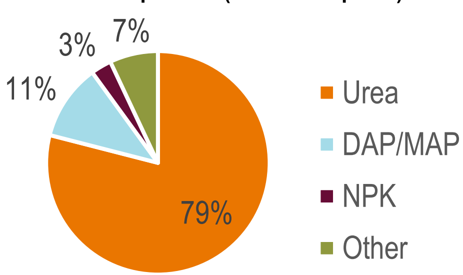
Environment before the National Hydrogen Mission

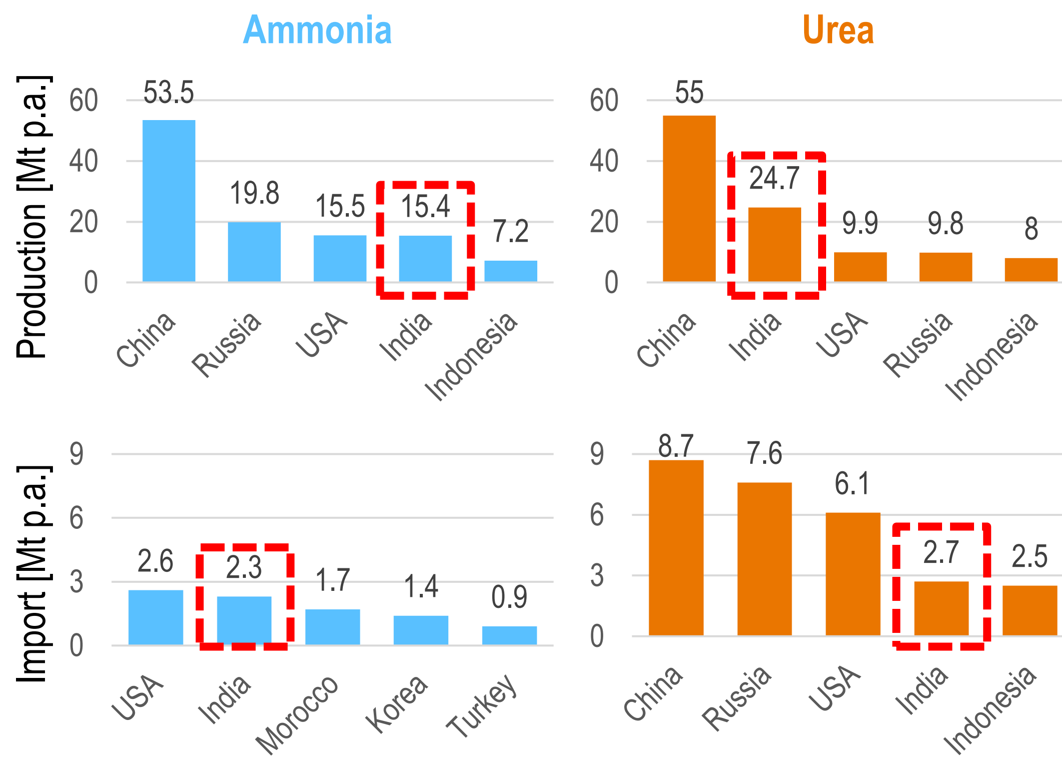
Supply

- Considerable production capacity
- Subsidy to cap the retail price
- New Urea Policy grouped by specific energy consumption

Demand

- 18% of global N-fertiliser consumption (20.4Mt p.a.).

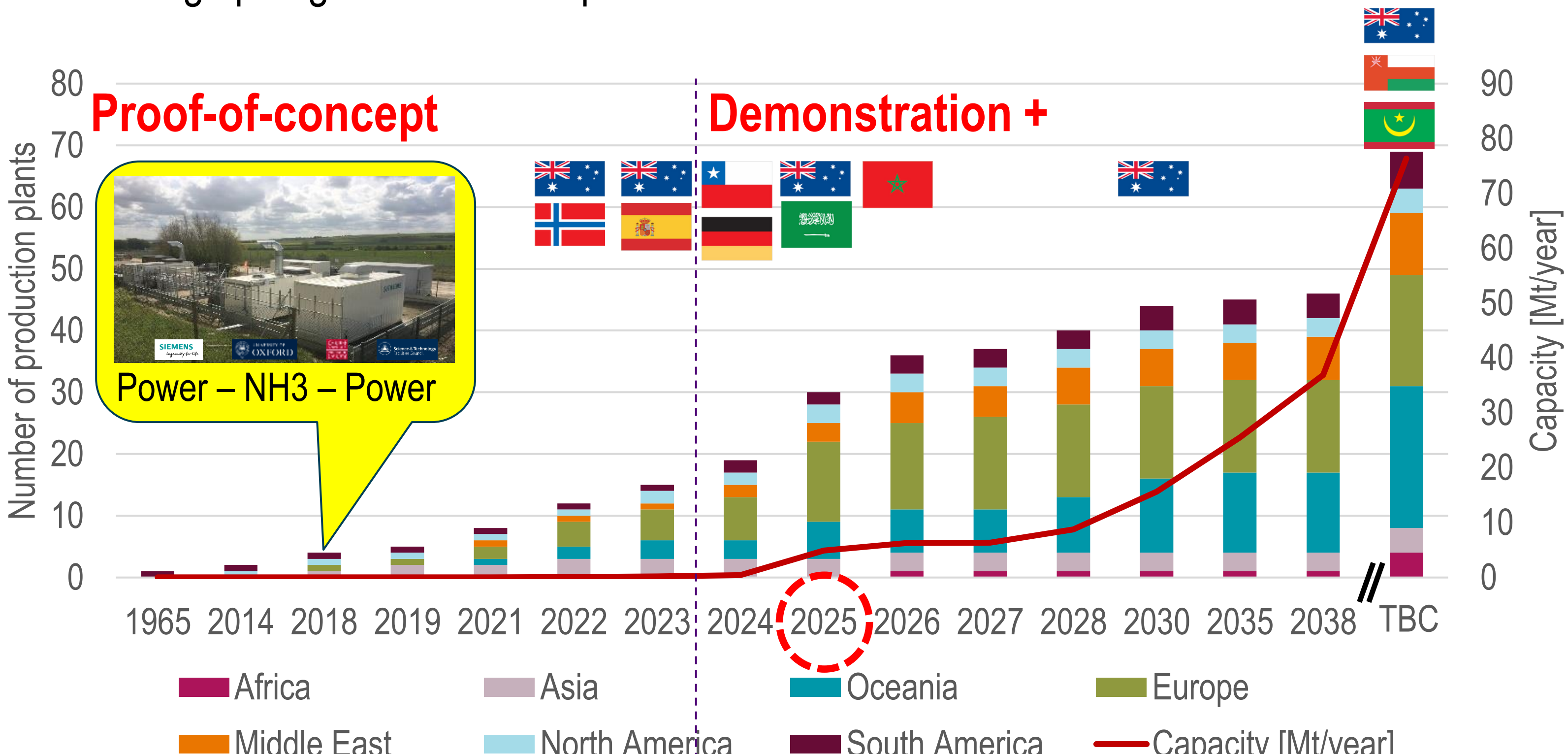




Sources: Yara Fertilizer Industry Handbook (2022) https://www.yara.com/siteassets/investors/057-reports-and-presentations/other/2022/fertilizer-industry-handbook-2022-with-notes.pdf/
Fertiliser Association of India, Annual Report 2018-2019 (2019)

The last few years have been interesting. Multiple projects have been announced with a notable jump coming in 2025 from kt to Mt capacity

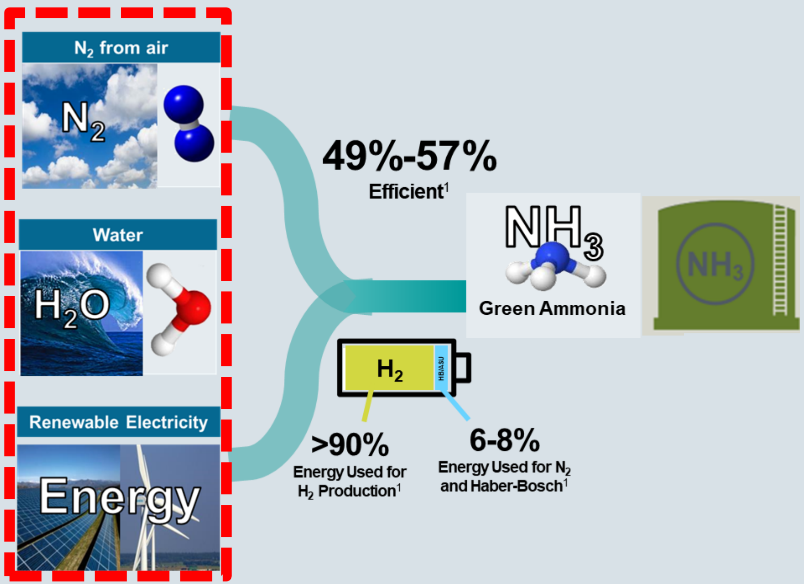
Global scaling up of green ammonia production



Source: Adapted from IRENA and AEA (2022), Innovation Outlook: Renewable Ammonia. ISBN 978-92-9260-423-3

Transition to ‘green’ ammonia production would reduce the current 1.3% of global CO_2eq emissions

Production of ‘Green’ Ammonia



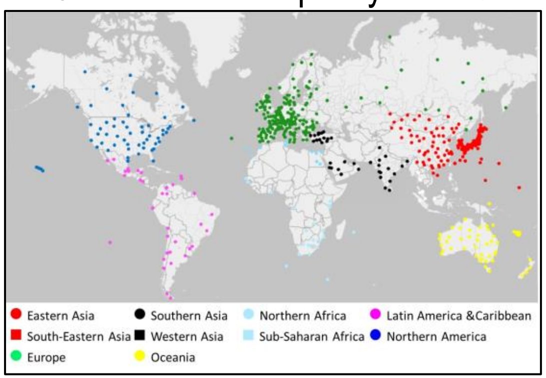
Energy Source	Process	Energy [GJ/t_{NH3}]	CO_2 Emissions [t_{CO2}/t_{NH3}]
Natural Gas	Steam Reforming	28	1.6
Naphtha	Steam Reforming	35	2.5
Heavy Fuel Oil	Partial Oxidation	38	3.0
Coal	Partial Oxidation	42	3.8
Electricity	Low Temp. Electrolysis	33 – 36	-
Electricity	High Temp. Electrolysis	26 – 30	-

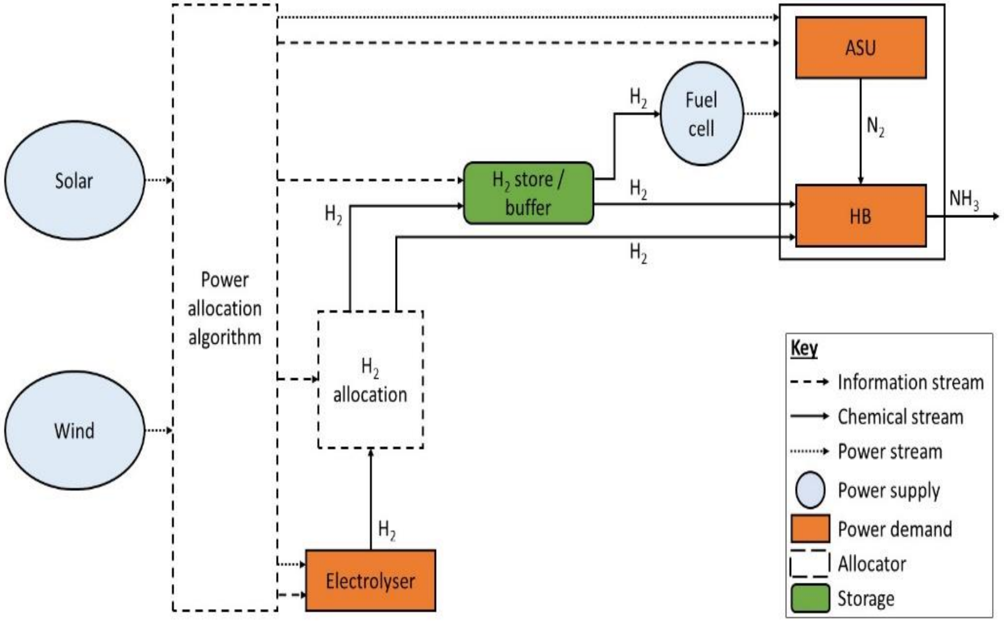
Sources: Zac Cesaro: *Assuming 58% electric efficiency of CCGT for all fuels (this assumption is not likely to be true, in the short term, as R&D levels are different for different fuels)
1. Assuming 60%-70% electrolyser efficiency, Haber Bosch 0.7 MWh/ton NH3 (IEA, The Future of Hydrogen, 2019)
2. NH3. Cracking: 76%-85% Cracking efficiency (based on LHV of H2 in fuel, not LHV of NH3) (S. Giddey, S. P. S. Badwal, C. Munnings and M. Dolan, “Ammonia as a Renewable Energy Transportation Media,” ACS Sustainable Chemistry & Eng., 2017.)
IRENA and AEA (2022), Innovation Outlook: Renewable Ammonia. ISBN 978-92-9260-423-3

The method used optimises the system design (VRE included) and operation to minimise the LCOA

Block Flow Diagram of the System Considered

- ~~Grid~~ / ~~Semi-Islanded~~ / Islanded
- Definition of the ammonia use
- Simplified production process
- Methods of flexibility considered:
  - ~~Battery~~
  - H_2 buffer
  - Curtailment
  - ~~Grid-connection~~
  - Reduced capacity factors





Source: Adapted from Nayak-Luke, R., Bañares-Alcántara, R., Wilkinson, I. Ind. Eng. Chem. Res. (2018) DOI:10.1039/D0EE01707H
Nayak-Luke, R & Bañares-Alcántara, R. Energy Environ. Sci., (2020) DOI: 10.1039/D0EE01707H

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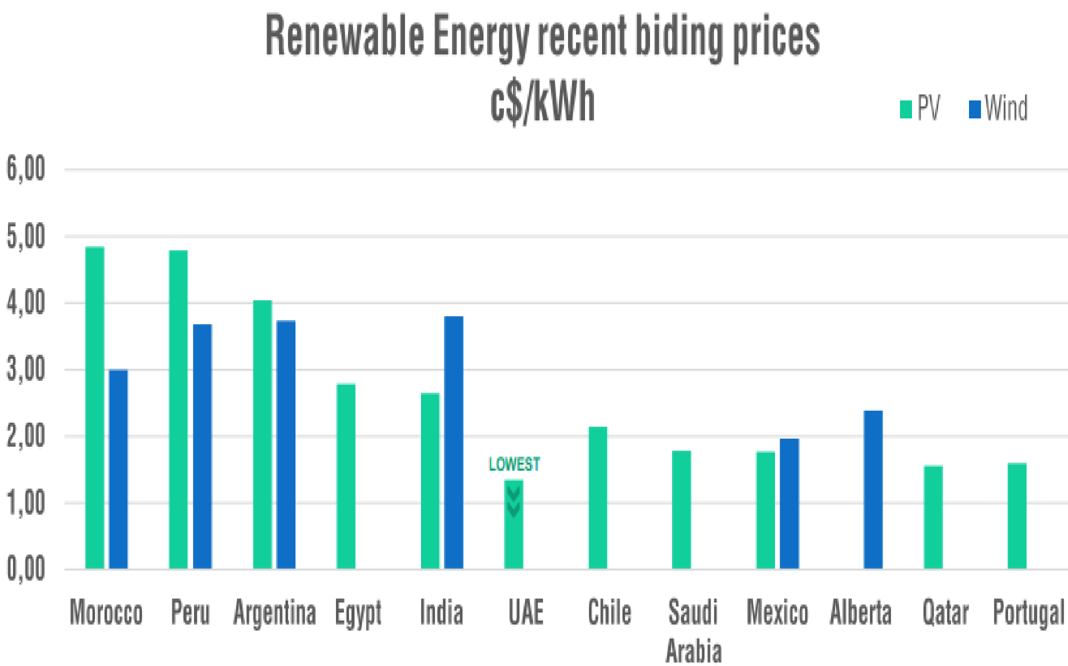
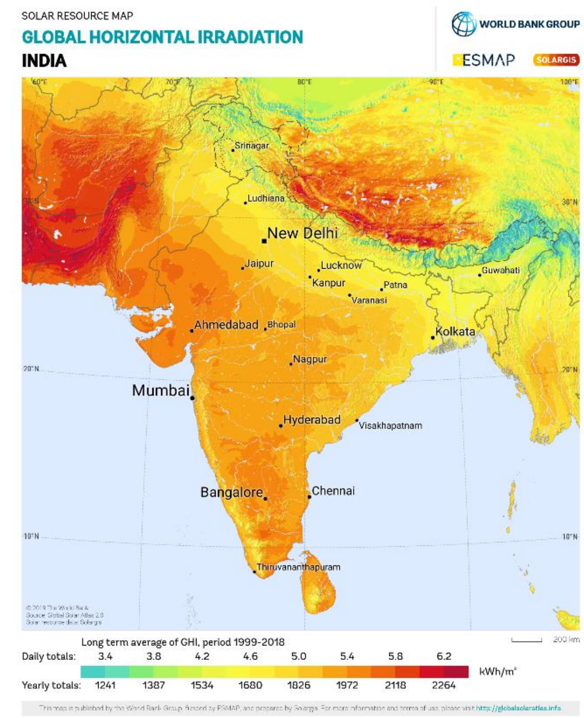
India is ideally placed for green ammonia production as one of the cheapest locations for VRE but particularly solar photovoltaic (PV)

Why Produce Green Ammonia in India?





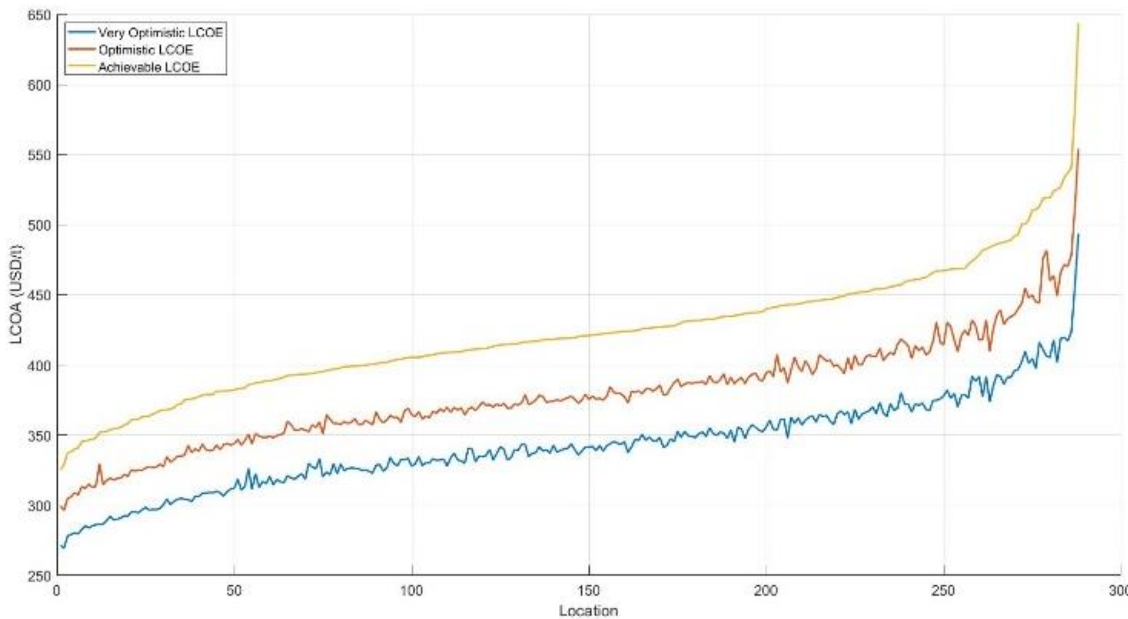
Sources: Ikken, B., et al., Power-to-X: Driver of Mediterranean Energy Market Integration. 2020, Ministry of Energy, Mines and Environment (IRESEN).
World Solar Atlas 2.0

288 locations considered, and the optimal plant design determined. High solar PV dependence means the LCOA is sensitive to LCOE development

Impact of the LCOA on the achievable LCOA

- ERA5 data for 1990-2019
- 1 hour temporal resolution
- 1° (110.6km) spatial resolution: 288 locations considered in total.

Three scenarios were considered that were based on the predicted installed cost of VRE in 2030.

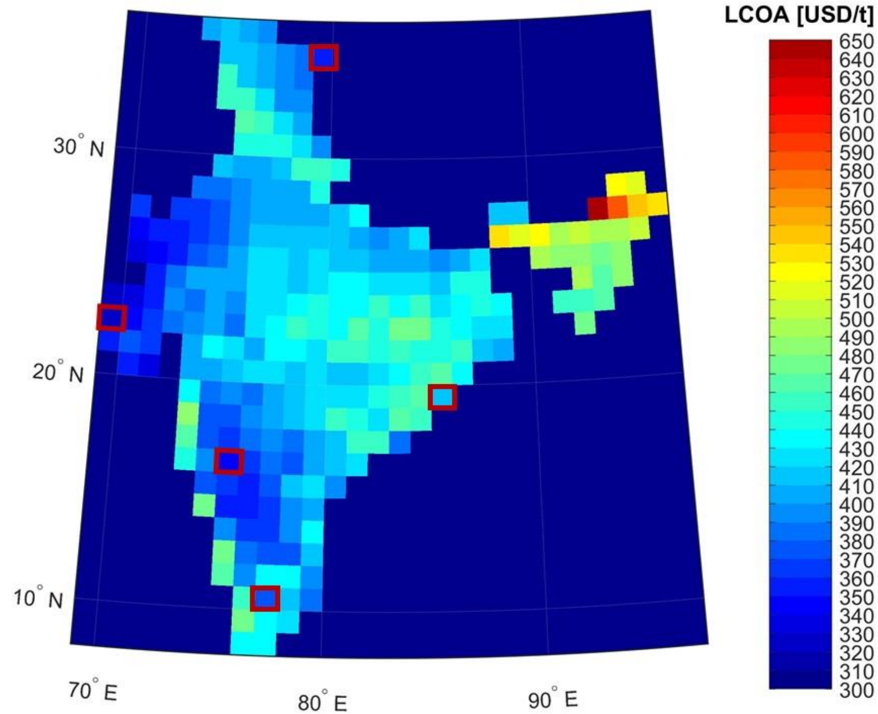


Source: Nayak-Luke, R. et al. J. Clean. Prod. (2022) DOI: 10.1016/j.jclepro.2022.132462

While the majority of India would by able to achieve low LCOA, there are certain areas in the West that are preferable due to the VRE resource

Best locations for green ammonia production

- Five locations of particular interest were selected (dashed red squares on the figure). These were selected not only for their predicted LCOA result but also for other reasons such as the Talcher coal gasification plant in Odisha and the pilot plant considered in Ladakh
- All of these locations were highly solar PV dependent <20% wind except for Gujarat (due to the wind resource)
- All locations employed a similar method of flexibility: preferring curtailment over a large hydrogen buffer

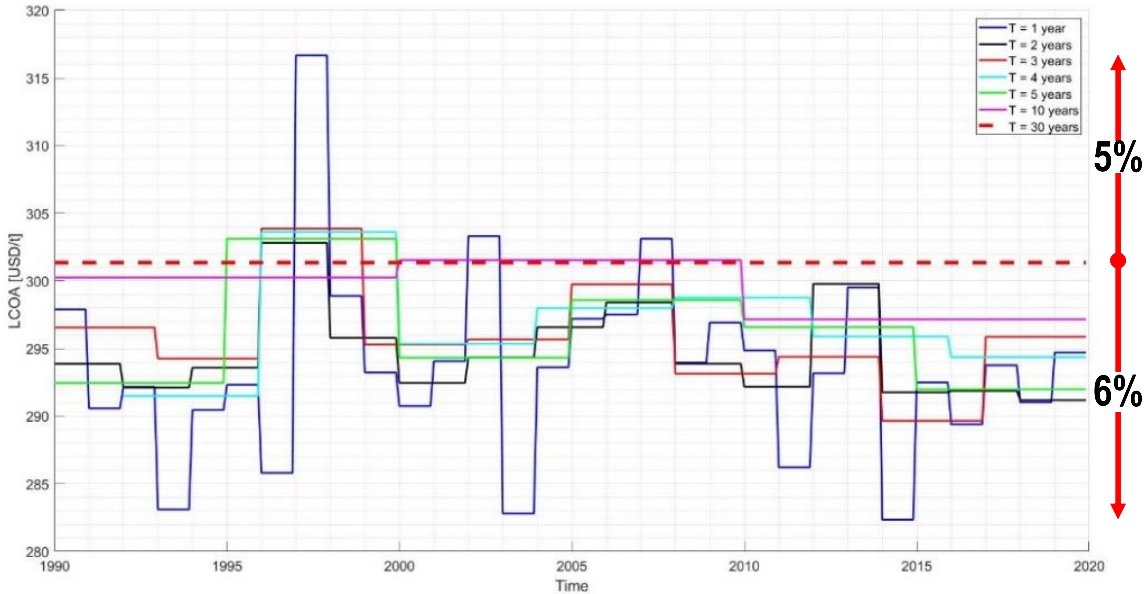


Source: Nayak-Luke, R. et al. J. Clean. Prod. (2022) DOI: 10.1016/j.jclepro.2022.132462

There can be notable deviation from the "true" solution if the length of the time period considered is insufficient.

Significance of the Time Period Considered

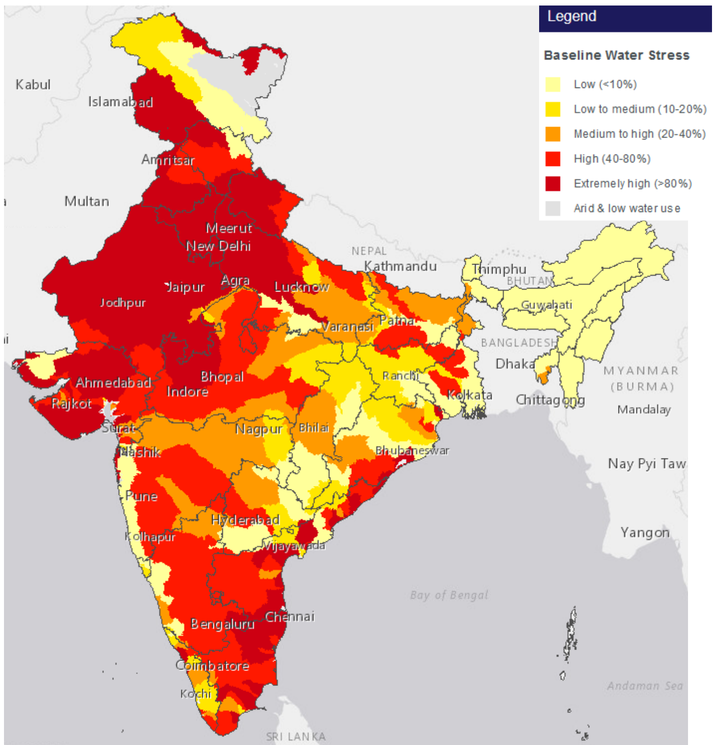
- The time period of data considered can have notable impact on the LCOA and is difficult to predict.
- However, the plant design can vary even more significantly than the LCOA.
- Location changes not only the capacity factors but also the shape of the power profiles and their alignment. While some learnings can be transferred each location requires careful consideration.



Sources: Nayak-Luke, R. et al. J. Clean. Prod. (2022) DOI: 10.1016/j.jclepro.2022.132462
Nayak-Luke, R. et al. at the Symposium on Ammonia Energy, Cardiff, UK (Sept 2022)

While not show-stoppers there are important limitations to consider when selecting the production location and product

Limitations: Water & Carbon availability



"55% of all ammonia worldwide is used for the production of urea, which also requires CO2, currently supplied as by-product of fossil-based hydrogen production"

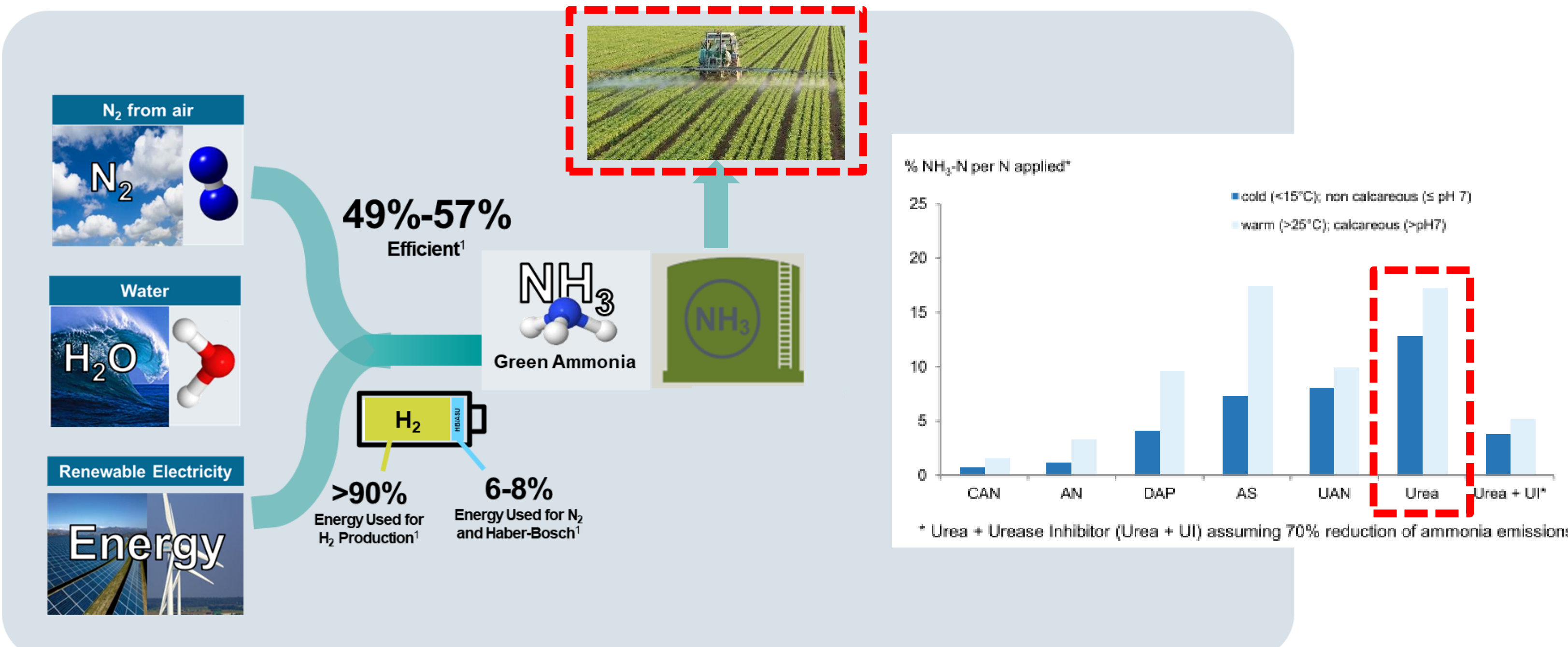
"Urea requires CO_2, which implies that a carbon-neutral source such as direct air capture (DAC) or biomass. Currently, DAC is relatively expensive with a reported cost in the range USD \$160-455/t_CO_2. In the long term, estimates for DAC vary in the range of \$65-200/t_CO_2"

"Air pollution is responsible for 18% of the total annual premature deaths in India"

Souce: https://www.indiawatertool.in/index.html & IRENA and AEA (2022), Innovation Outlook: Renewable Ammonia. ISBN 978-92-9260-423-3
Mishra, S. et al. Nat Geoscience (2023) DOI: 10.1038/s41561-023-01138-x

Current N-fertiliser demand is globally significant and is dominated by urea. However, urea requires a carbon feedstock and has notable volatilisation.

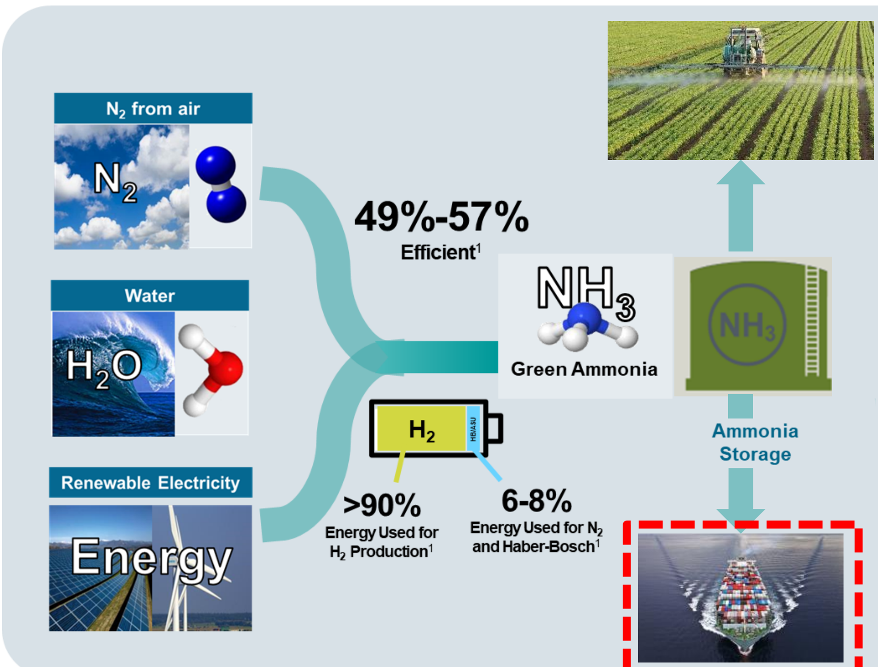
Demand for ‘Green’ Ammonia: Nitrogenous Fertiliser

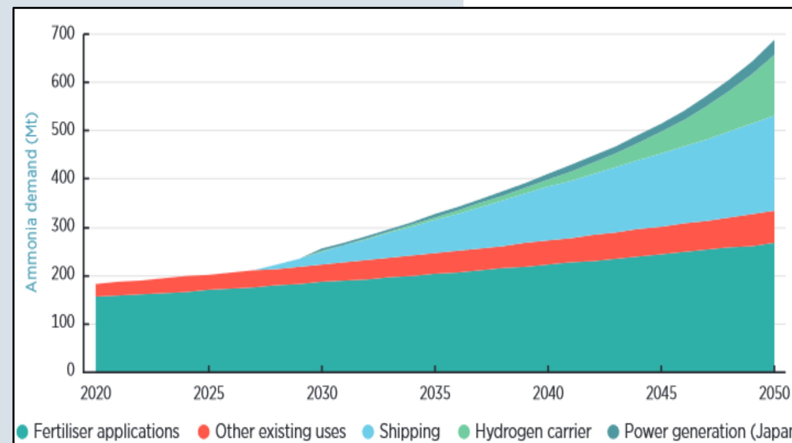


Sources: Zac Cesaro: *Assuming 58% electric efficiency of CCGT for all fuels (this assumption is not likely to be true, in the short term, as R&D levels are different for different fuels)
1. Assuming 60%-70% electrolyser efficiency, Haber Bosch 0.7 MWh/ton NH3 (IEA, The Future of Hydrogen, 2019)
2. NH3. Cracking: 76%-85% Cracking efficiency (based on LHV of H2 in fuel, not LHV of NH3) (S. Giddey, S. P. S. Badwal, C. Munnings and M. Dolan, “Ammonia as a Renewable Energy Transportation Media,” ACS Sustainable Chemistry & Eng., 2017.)
Yara Fertilizer Industry Handbook (2022) https://www.yara.com/siteassets/investors/057-reports-and-presentations/other/2022/fertilizer-industry-handbook-2022-with-notes.pdf/

Driven by the IMO target and Poseidon Principles, shipping sector demand for ammonia is likely to be significant and India is ideally located.

Demand for ‘Green’ Ammonia: Shipping Fuel





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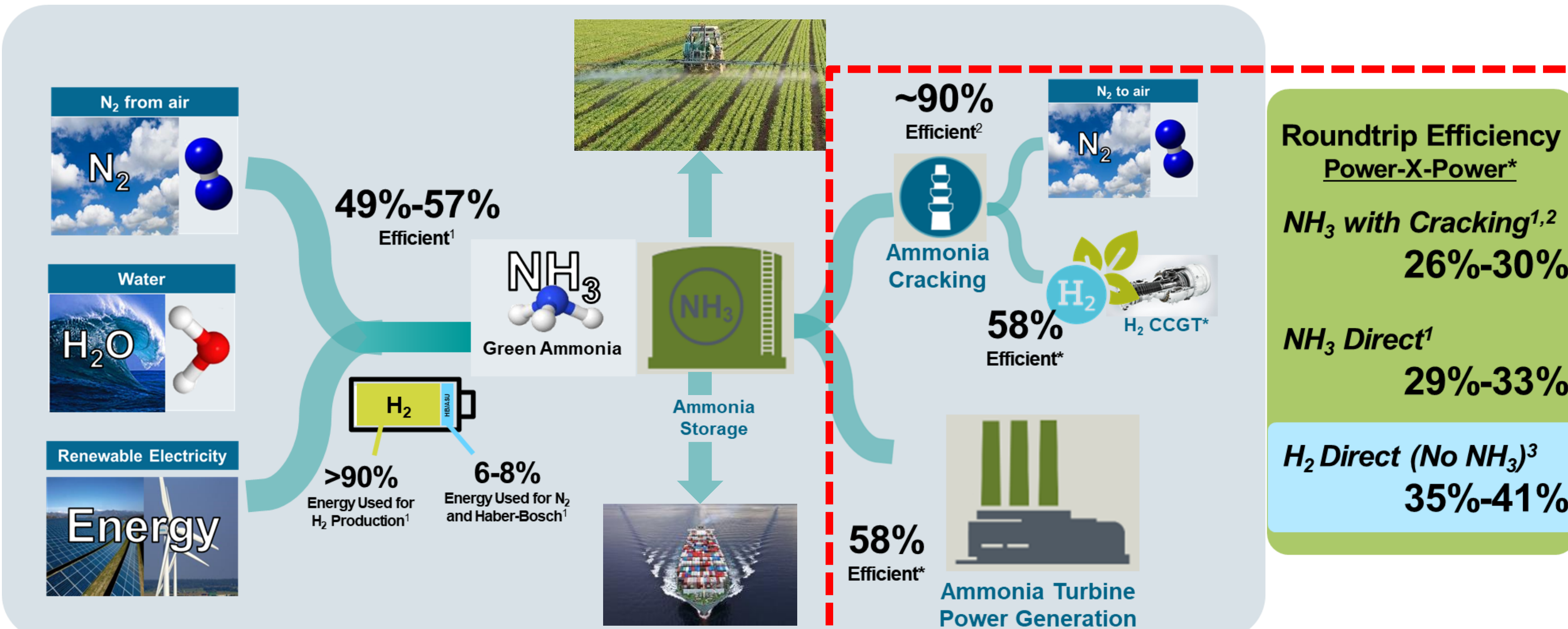
Green ammonia can provide grid flexibility through demand and supply. The value of this flexibility will become more significant at high VRE penetration.

Demand for 'Green' Ammonia: Energy vector / Energy storage / Flexible Demand



Sources: Zac Cesaro: *Assuming 58% electric efficiency of CCGT for all fuels (this assumption is not likely to be true, in the short term, as R&D levels are different for different fuels)
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Conclusion

- India is a key global market for N-fertilizer, but imports a notable amount of natural gas, ammonia and urea.
- Due to its low VRE costs the achievable LCOA at multiple sites, particularly on the West coast that are very promising.
- There are limitations such as water and carbon availability that do need to be considered when locating production plants.
- India is ideally placed to capitalise on additional uses of green ammonia. Namely its use as a shipping fuel and as an energy vector. With the latter of these India, should consider the mutual sector coupling benefits that may be achievable with grid development and electrification of industry such as ammonia production.

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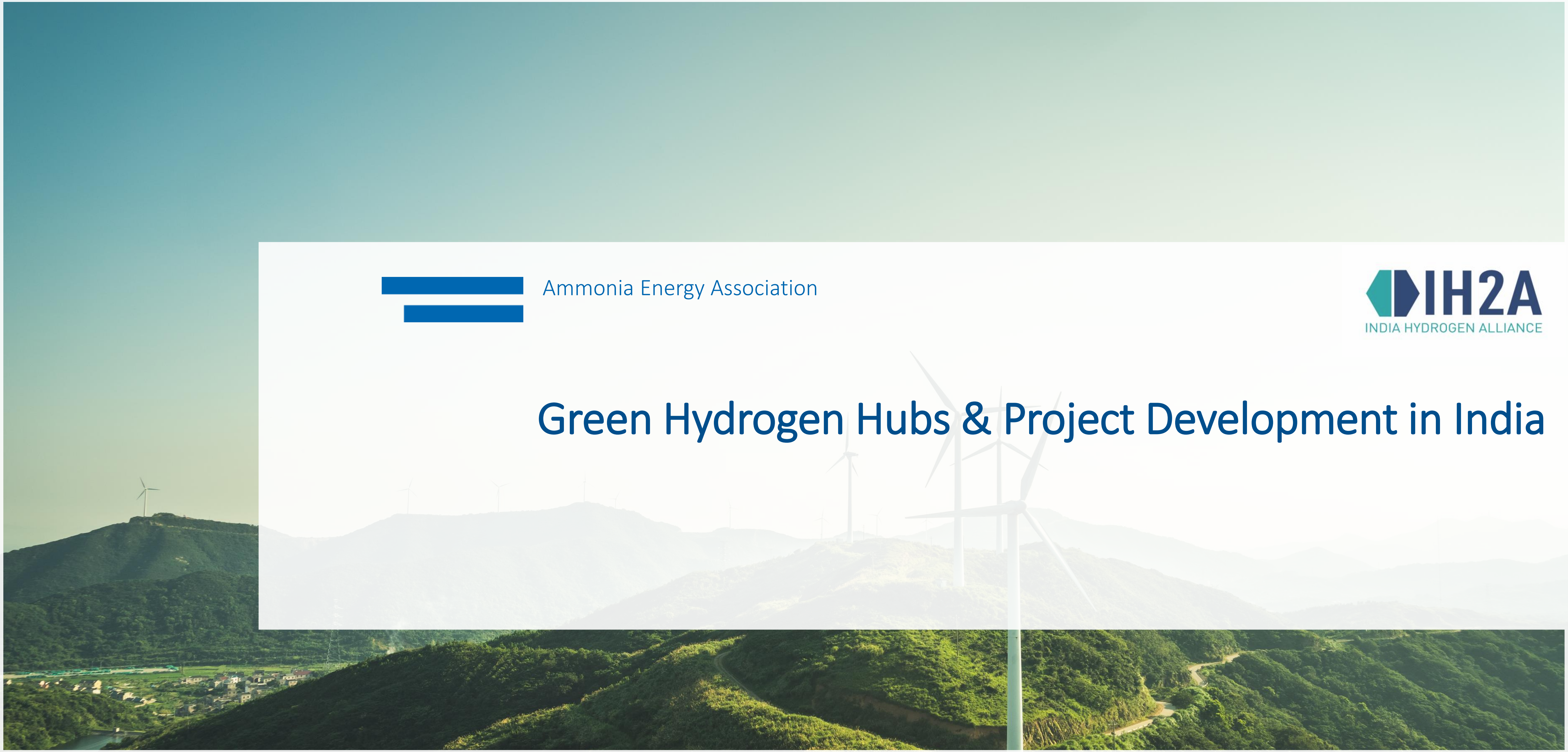
- Luke Hatton
- Zac Cesaro
- Ian Wilkinson

Thanks for the use of Aspen Plus, Aspen Economic Evaluator and MATLAB (including its numerous applications) under AspenTech and MATLAB academic licenses respectively.



Ammonia Energy Association

IH2A
INDIA HYDROGEN ALLIANCE

Green Hydrogen Hubs & Project Development in India

FTI CONSULTING

March 20 2023

National Green Hydrogen Mission

Highlights & Allocations

NATIONAL GREEN HYDROGEN MISSION – Initial outlay INR 19,744 crores

1) **Green Hydrogen Demand Aggregation**
   - Domestic Demand & Exports: Govt to specify minimum share of consumption of green hydrogen or derivative (green ammonia/ methanol) by designated consumers as energy or feedstock - year wise trajectory of minimum share of consumption to be decided by Empowered Group (EG). Mission will facilitate export opportunities.
   - Competitive Bidding: Demand aggregation and procurement of green hydrogen, ammonia through competitive bidding route. MNRE will develop suitable regulatory framework for certification of Green Hydrogen and its derivatives.
2) **National Incentive Schemes for Production (Electrolyser, Green Hydrogen)**
   - Strategic Incentives for Green Hydrogen Transition (SIGHT) scheme - INR 17,490 crores initial outlay upto 2029-30 (manufacture of electrolyser, production of green H2)
3) **Initial Pilot Project & Green Hydrogen Hubs allocations**
   - INR 455 crores for low-carbon steel (upto 2029-30), INR 611 crore for mobility and shipping pilots (upto 2025-26)
   - Green Hydrogen Hubs INR 400 crores (upto 2025-26), with at least two hubs in initial phase
4) **Public-private partnership framework for R&D (Strategic Hydrogen Innovation Partnership - SHIP)**
   - INR 400 crores dedicated R&D fund
5) **INR 400 crores for Governance and Components** (Policy Framework and Planning; Infrastructure Development, Regulations & Standards, Skill Development & Awareness)
   - Empowered Group (EG) - Cabinet Secretary, Secretaries, industry experts to guide
   - Advisory Group – PSA, experts to advise EG on technical matters
   - MNRE Mission Secretariat - implementation

IH2A PROPOSED PLAN TO GOVT OF INDIA, JUNE 2022

IH2A INDIA HYDROGEN ALLIANCE

National 25/25 Green H2 Development Plan – 25 H2 project clusters by 2025

First-Generation National Green H2 Projects to accelerate commercialisation, learning rates, induce demand at critical scale

Scalable, Co-located National Green H2 Projects using RE-Electrolysis, Gasification across RE-rich coastal states ('India's Hydrogen Valleys')

18 GH2 Project Clusters (w/RE-Electrolysis)	7 Green H2 Bharat Cities - Waste-to-H2 Municipal Projects (with Gasification)	25 National Large-Scale Projects by 2025
Industrial, Heavy-Duty Transport Offtake, each potentially scalable to GW capacity	Local Industrial, Municipal Transport Fleets	150 MW Installed Electrolyser Capacity Green H2 Use in Industrial, Heavy Duty Transport Future Coastal Shipping, Land Transport (Liquid, Gas)

Five Key Enablers

CENTRAL GOVT	National Green H2 Dev Corp (NHDC) & Public-Private Taskforce	State Green H2 Plans, Nodal Office	Project Dev SPVs, Consortia	Public Funding/ Infra, National Innovation Status	National Testing/ Certification, Standards, Skilling
NGHM	Being Evaluated	State Partnerships	Two H2 Hubs	USD 2 bn+ allocated	Technical Advisory Group proposed

INDIA HYDROGEN ALLIANCE

State-Level

Five National Green H2 Hubs

Multi-use/offtake SPVs

Co-located Production-Use

150 MW Electrolyser Capacity

USD 360 mn, 3-year Public Finance Support

Oversight by NHDC, Bharat H2 Taskforce & State-Level Green H2 Advisory Groups

40 MW GREEN H2GUJ
National Chem-Steel-Refinery-CGD Hub

Ankleshwar-Vadodara-Hazira (GUJ)

USD 78 mn public spend, c8000 tonnes pa Green H2 production & offtake, cut 8 Mmt CO2 in a decade

10MW Green H2, NH3/ Fertilizer Hub (Ankleshwar)
10MW GreenH2 Steel Plant (Hazira)
10MW GreenH2 Refinery (Vadodara)
5MW H2-CGD Networks (Vadodara)
5MW Heavy-Duty Transport/ Forklifts (Vadodara)
Waste-to-H2 City (Vadodara/ Dahej/Hazira)

30 MW GREEN H2KAR-AP
National Steel-Chem-CGD Hub

Bellary-Nellore-Krishnapatnam (KAR-AP)

USD 68 mn public spend, c5000 tonnes pa Green H2 production & offtake , eliminate 5 Mmt CO2 in a decade

10MW GreenH2 Steel Plant (Bellary)
10MW Green H2, NH3 Hub (Nellore)
5MW H2-CGD Networks (Nellore)
5MW Heavy-Duty Transport/ Forklifts (Krishnapatanam)
Waste-to-H2 City (Nellore)

30 MW GREEN MAH2
National Steel–Refinery–Transport-CGD Hub

Mumbai-Pune-Dolvi (MAH)

USD 68 mn public spend, c5000 tonnes pa Green H2 prodn & offtake, cut 5 Mmt CO2 in a decade

10MW GreenH2 Steel Plant (Dolvi)
10MW Green Refineries (Mumbai)
5MW H2-CGD Networks (Pune/Mumbai)
5MW Heavy-Duty Transport/ Forklifts (Nhava Sheva)
Waste-to-H2 City Projects (Mumbai/ Pune)

30 MW GREEN H2VIZAG
National Refinery-Steel-Transport-CGD Hub

Vizag (AP)

USD 68 mn public spend, c5000 tonnes pa Green H2 prodn & offtake , cut 5 Mmt CO2 in a decade

10MW Green H2 Refinery (Vizag)
10 MW Green Steel (Vizag)
5MW H2-CGD Networks (Vizag)
5MW Heavy-Duty Transport (Vizag)
Waste-to-H2 City Projects (Vizag)

20 MW GREEN H2KOCHI
National Chem – Transport -CGD Hub

Kochi (KER)

USD 45 mn public spend, 4000 tonnes pa Green H2 prodn & offtake, cut 4 Mmt CO2 in a decade

10MW Green H2 Refinery (Kochi)
5MW H2-CGD Networks (Kochi)
5MW Heavy-Duty Transport/ Forklifts (Kochi)
Waste-to-H2 City Projects (Mumbai/ Kochi)

**indicative project SPV structures in following slides; project locations, SPV contracting & award to be done by NHDC, Bharat H2 Taskforce*
^over and above individual private sector project development and investments

Large-Scale Green H2 Hubs & Project Development Challenges

1

NGHM Governance Structure – important for large-scale project planning

- Urgency to set up Empowered Group, Technical Advisory Group and Mission Secretariat within next 3-4 months
- Public-Private (Industry) representation across all three levels

2

National Green Hydrogen Development Corporation (NGHDC) – central strategic planning entity, with project dev focus

- Dedicated to hydrogen commercialisation taking a value-chain perspective, aggregate demand, design and allocate state incentives/subsidies
- Undertake techno-commercial studies of large-scale hubs and projects, for integrated planning, investment decisions and incentive allocation
- Focus on near-term domestic industrial demand, followed by future export demand, for project planning

3

Green Hydrogen Offtake Guarantees / Purchase Obligations – to induce demand, develop green hydrogen market

- Defined-price offtake guarantee, covered with subsidy support to decarbonize hard-to-abate industries (fertilizer, steel, refineries, chemicals)
- Public-owned enterprises, as well as private entities – supported with incentives

4

Prioritize Green Hydrogen Hubs, designate 'National Infrastructure' status

- Learning from EU 'Hydrogen Valleys' – gradual scale up to GW scale in hubs/clusters, rather than stranded projects
- National banking policy for hubs, large-projects

5

H2 Production Plants, Large-Scale Hubs, Storage and Infrastructure to be included within SIGHT scheme

- Focus on building delivery to end-user – entire supply-side value chain to be included with definition of 'production'

Thank you

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