Ammonia Project Features

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

Using surplus hydroelectricity for ammonia production in Paraguay

Olivier Mussat
CEO, ATOME

ATOME

Ermanno Filippi
CTO, Casale

CASALE

Santiago Del Valle
MD, URBAS Energy-Ingeser

urbas

In conversation with:

Kevin Rouwenhorst
Technology Manager, AEA

AMMONIA ENERGY ASSOCIATION

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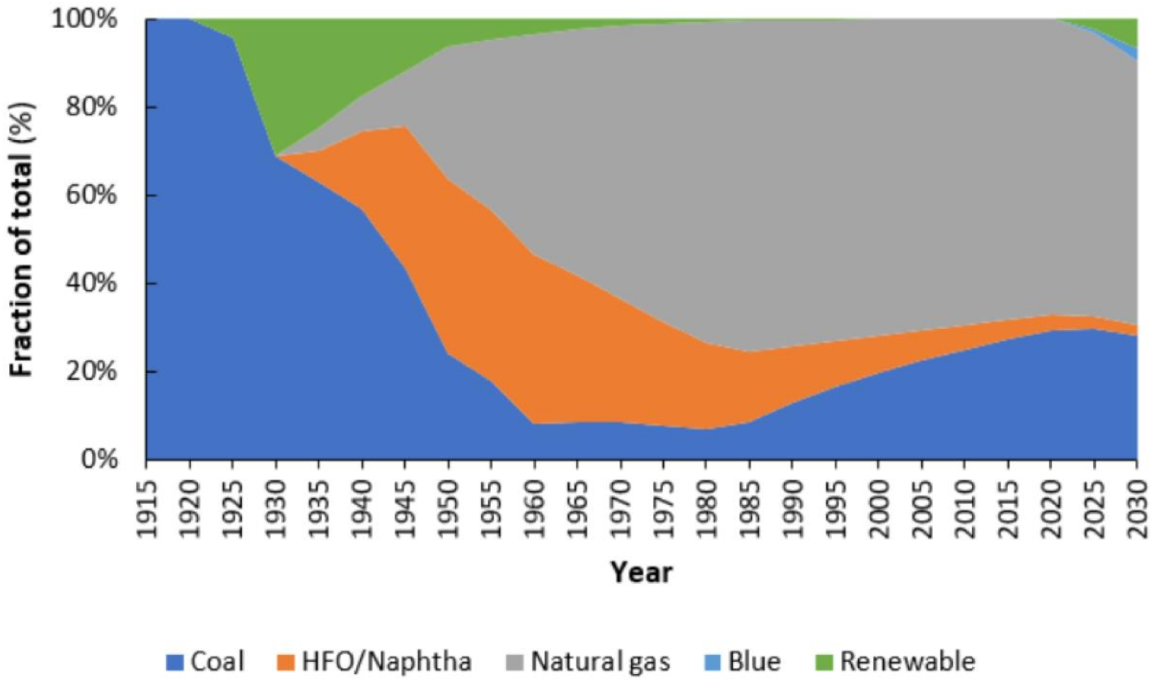
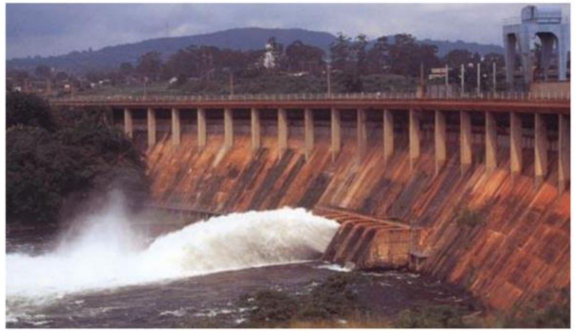
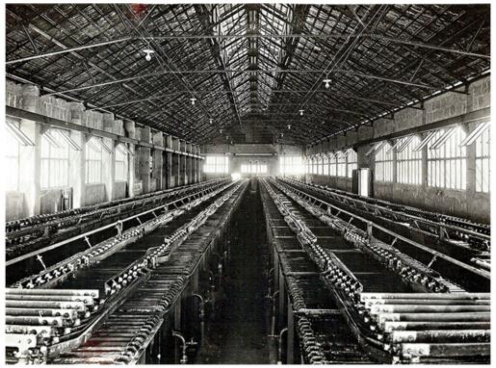
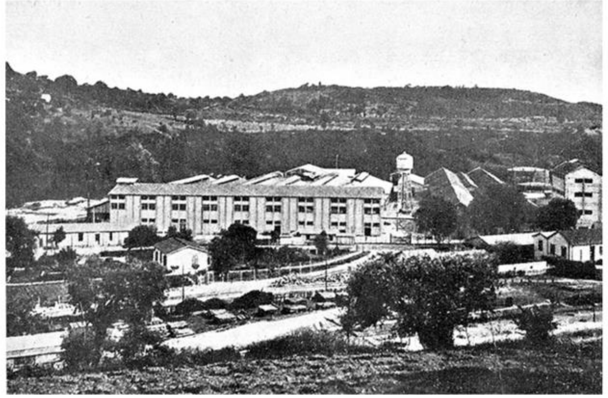
Historical electrolysis-based ammonia production

- Grid-connected (hydropower)
- Up to 100-150 MW
- **First plant**: 1921 (Terni / Nera Montoro, Italy)









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Surplus hydropower at the Itaipu Dam

Ammonia Project Features

(Wednesday 31 May, 3PM CET, online via Zoom Webinar)

Scaling flexible ammonia production in China to gigawatt-size

Per Aggerholm Sørensen
R&D Director eChemicals and Synthesis Technology, Topsoe

TOPSOE

Carol Xiao
Director Business Development, ISPT

Institute for Sustainable Process Technology

In conversation with:

Kevin Rouwenhorst
Technology Manager, AEA

AMMONIA ENERGY ASSOCIATION

ATOME

GREEN HYDROGEN & AMMONIA PRODUCTION FOR THE WORLD

APRIL 2023

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UK HFCA

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GREEN HYDROGEN & AMMONIA

ATOME | At a glance

ATOME WILL BE THE LARGEST UK BASED GREEN HYDROGEN AND AMMONIA PRODUCER BY 2025

The only London Stock Exchange company focused on the production & sale of green hydrogen and ammonia

EARLY MOVERS AT SCALE

120MW

Baseload Power Purchase Agreement for initial project in Paraguay

FIRST TO MARKET

Front-End Engineering and Design on track for completion in Q2 2023

100% RENEWABLE

Largest announced project in Latin America by 2025, powered by hydro

100,000

tonnes of potential green ammonia per year in 2026*

WORLD-SCALE

Current pipeline of over 621MW of projects globally

OUR BUSINESS

Fast-track

Targeting locations where infrastructure and readily available low-cost power are available

Ammonia In Agriculture

Delivering green ammonia to existing markets displacing imported fossil fuel based fertilisers

Clean Fuel

Providing a clean energy solution for heavy road transport and shipping

*Subject to final plant design

ATOME | Growing our existing pipeline, globally

ATOME | Expert, Experienced Management

Peter Levine

Chairman

Peter MA (Oxon) is the Chairman and largest shareholder of ATOME. As the executive Chairman, founder and single largest shareholder of the then FTSE 250 Imperial Energy, he oversaw the growth from 25p at flotation to 1250p until its $2.4 billion sale in January 2009

Between 1993-2008, Peter Levine was Deputy Chairman and then Chairman of the then FTSE 250 listed steel construction company, Severfield-Rowen (now Severfield), and was also Chairman of Keltbray group

Olivier Mussat

Director and CEO

Olivier BA, MS, has joined ATOME from being the Chief Investment Officer of Global Energy at the IFC, part of the World Bank Group

After starting his career as a field engineer in the power sector, he is vastly experienced in funding and managing energy infrastructure assets for Oil & Gas, Power & Renewables.

He has lead over $500M of equity investments in early stage companies and over $30bn of corporate and structured debt finance transactions

James Spalding

Director and President of ATOME Paraguay

James BA, MA, was the Paraguayan General Director of the jointly owned Paraguay-Brazil hydroelectric dam Itaipu Binacional between 2013-2018, the second largest hydroelectric dam in the world

Prior to that he was for six years the Ambassador of Paraguay in the US, serving in 2009 as Dean of the Latin American Ambassadors Group (GRULA). He has also served as Paraguay Minister of Finance and as the Governor of Paraguay to the IDB and World Bank group

Mary-Rose de Valladares

Independent Non-Executive Director

Mary-Rose MA, MBA, was the long-standing General Manager of IEA Hydrogen. With expertise in renewables and hydrogen, she was formerly at the U.S. DOE National Renewable Energy Laboratory (NREL) serving as the renewable and energy efficiency developer at the Centennial Olympics in Atlanta, GA, USA,

She served on the National Hydrogen Association Board of Directors and founded New Mexico Solar Energy Industry Association

Terje Bakken

Director for Ammonia and Fertiliser Markets

Terje graduated with an MBA from School of Management, Bath University. He started his fertiliser career with Norsk Hydro and Yara International in Oslo. He was then Senior Vice President at Yara International´s Executive Management Team for 8 years

Terje started to work with EuroChem in 2013 as a member of EuroChem´s management board, responsible for global marketing and sales operations

ATOME

GREEN HYDROGEN & AMMONIA PRODUCTION

PARAGUAY | 421MW PROJECTS

COUNTRY PROFILE

- BB+ Fitch rating, a stable open economy. Low tax and trade barriers
- In 2020, Paraguay exported US$2.1 billion in Soybeans, making it the 4th largest exporter of soybeans. Agriculture retains 20% of the country's total employment
- Landlocked country heavily dependent on land and river transport for the import/export of goods
- Founding member of Mercosur bloc enjoying free trade and travel with Brazil, Argentina and Uruguay
- Paraguay is powered 99% by renewable energy, primarily from the Itaipu Dam, making it one of the largest exporters of electricity in the world. Paraguay exported roughly US$1.44 billion worth of electricity to Brazil in 2020

PARAGUAY |KEY FACTS

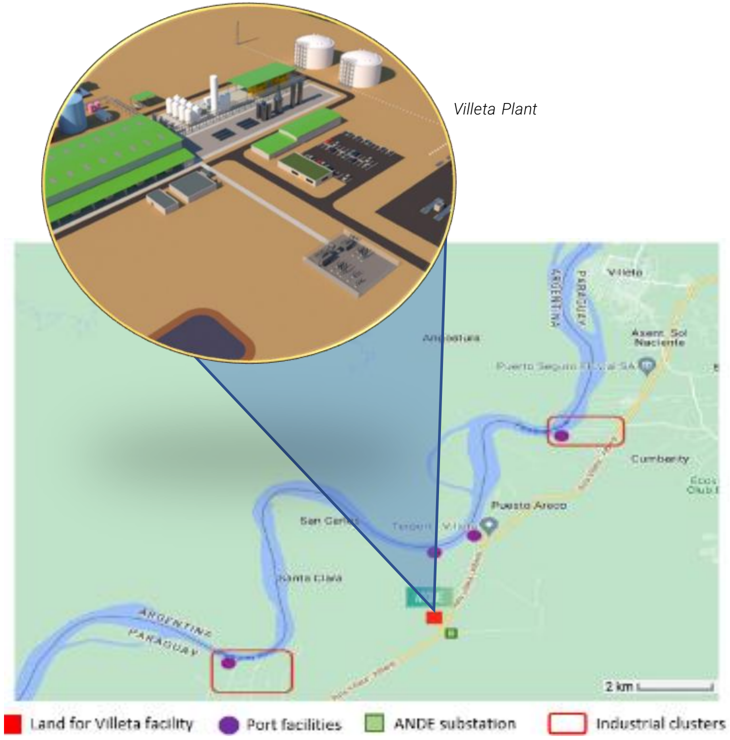
Corporate Tax Rate	10%
GDP	4.5% growth in 2021 (Fitch, 2021)
Energy Policy	Reduce dependency on hydrocarbons and capitalise on hydroelectric capabilities
Fertiliser Consumption	396.37 kg/ha (twice the global average in 2017)
Fertiliser Import	US$601 million (2021)
Annual Transport Sector Growth (2012-19)	Cars (11.6%), buses (4.6%) and trucks (6.6%)

TARGET MARKET

- Targeting domestic offtake markets for hydrogen and ammonia products for the agriculture industry. As of 2020, ammonium nitrate import in Brazil was 1.15 million tonnes that accounts for 13.71% of the world's ammonium nitrate import. Brazil imports 85% of its fertiliser needs
- Transport sector - reliance on HGVs and the world's third largest fleet of barges to transport industrial production - both need to be decarbonised. MOUs signed with the Paraguay aviation authority and the Paraguay barge association

LATIN AMERICA'S LARGEST GREEN AMMONIA FACILITY BY 2025

- PPA signed with ANDE, the national power company of Paraguay for 120MW providing 100% green power from the Itaipu Dam
- 75 acres of land now purchased with available access to water and adjacent to the Villeta substation and in close proximity to industrial clusters and port facilities on the country's primary import/export route
- Operational within 3 years and capable of producing up to 100,000MT/pa of green ammonia by end 2025
- Appointed Urbas Energy Ingeser-TSK and Casale as the FEED contractor for 120MW Villeta Project with a view to FEED completion and Final Investment Decision
- Natixis appointed as International Financial Adviser to structure and secure financing for the project and signed a Mandate Letter with the Inter-American Development Bank
- MOU signed with Puma Energy Paraguay S.A. in relation to hydrogen in Paraguay



NEXT STEPS

- Completion of FEED study and Environmental Social Impact Assessment (ESIA)
- FEED Completion and Final Investment Decision in 2023
- Appointment of EPC contractor with main sub-packages to be identified and to be tendered. Construction to begin in H2 2023
- Firm interest already shown from offtakers in all of ATOME's prospective Paraguay production

PARAGUAY | 421MW Projects

PHASE TWO YGUAZU – 300MW

ATOME is upscaling its original Phase 2 projection from 250 to 300MW making a total of over 420MW for both phases in Paraguay

Targeting Phase 2 commencement of production for 2027 assuming PPA agreed by end 2023

NEXT STEPS

- Additional PPA in Paraguay – already in discussions with ANDE for 300MW
- Select site in close proximity to Yguazu substation
- Appointment of FEED and EPC contractor with main sub-packages to be identified and to be tendered
- Leveraging on learning curves following 120MW project to accelerate 300MW project


Itaipu Dam

ATOME | Outlook

ATOME Projected Timeline	2021	2022	2023	2024	2025	2026
ATOME admission to London Stock Exchange	✓					
MOBILITY						
Mobility Division Created		✓				
First electrolyser ordered		✓				
First revenue for Mobility Division			→			
Mobility Division expansion			→	→	→	→
VILLETA						
Binding PPA for new Villeta Project signed		✓				
AECOM appointed as Owners Engineer		✓				
Land acquired for Villeta		✓				
FEED contractors appointment		✓				
PPA extended to 120MW		✓				
FID expected for Villeta (120MW)			H2			
Villeta build out			→	→	→	
Villeta commencing production					→	→
YGUAZU						
Yguazu 300MW PPA			→			
FID expected 300MW Yguazu			→	→		
Yguazu build out				→	→	→
Yguazu commencing production						→
ICELAND / COSTA RICA						
Green Fuel ehf acquired	✓					
National Ammonia Corporation formed			✓			
Securing PPA			→	→		
FEED				→	→	
FID					→	

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420 SPECIALISTS FOCUSED ON DELIVERING VALUE

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LUGANO - SWITZERLAND

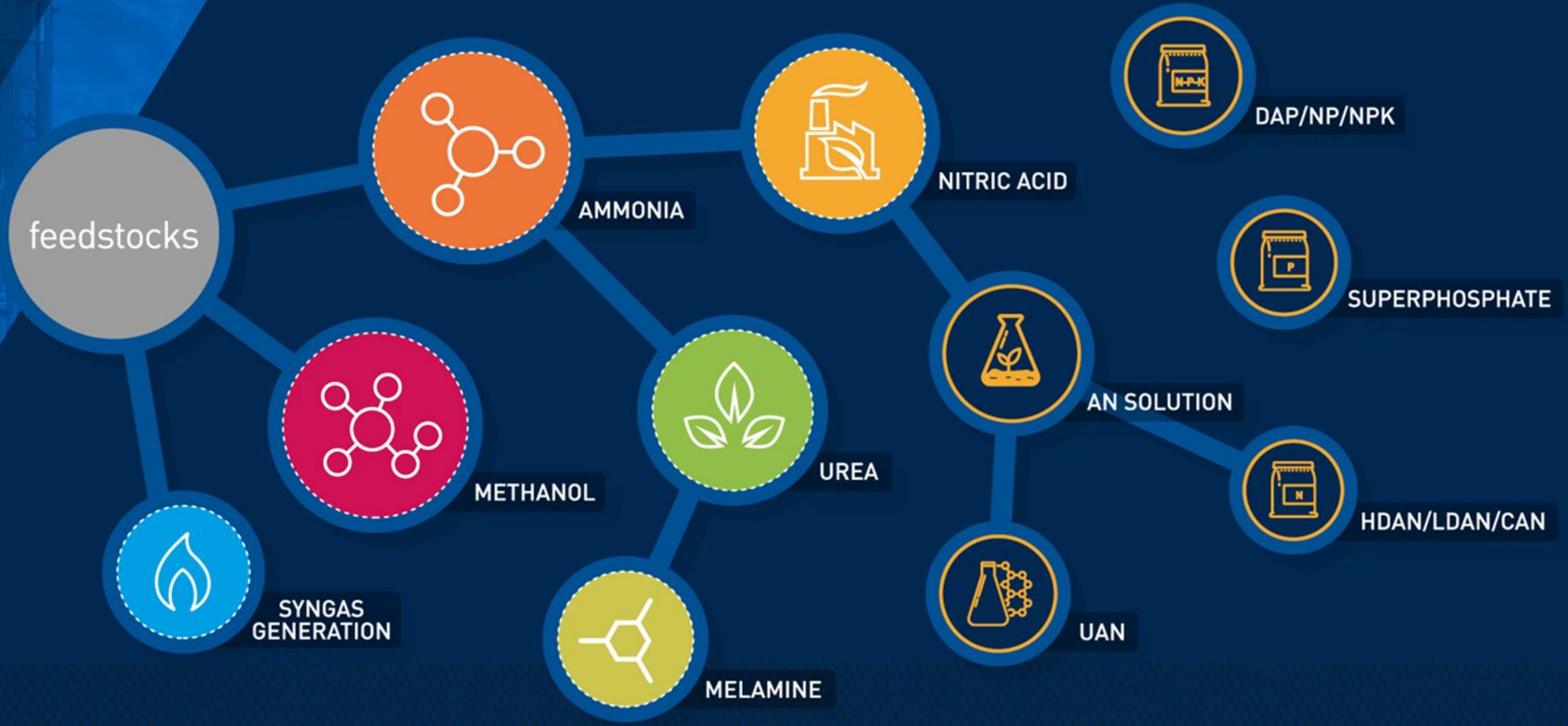
260 PROFESSIONALS

CASALE PROJECT

PRAGUE - CZECH REP.

160 PROFESSIONALS

TECHNOLOGICAL PORTFOLIO



CASALE

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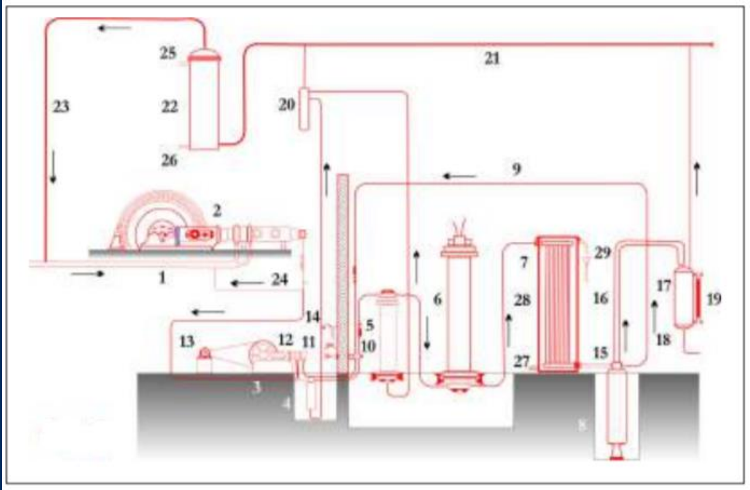
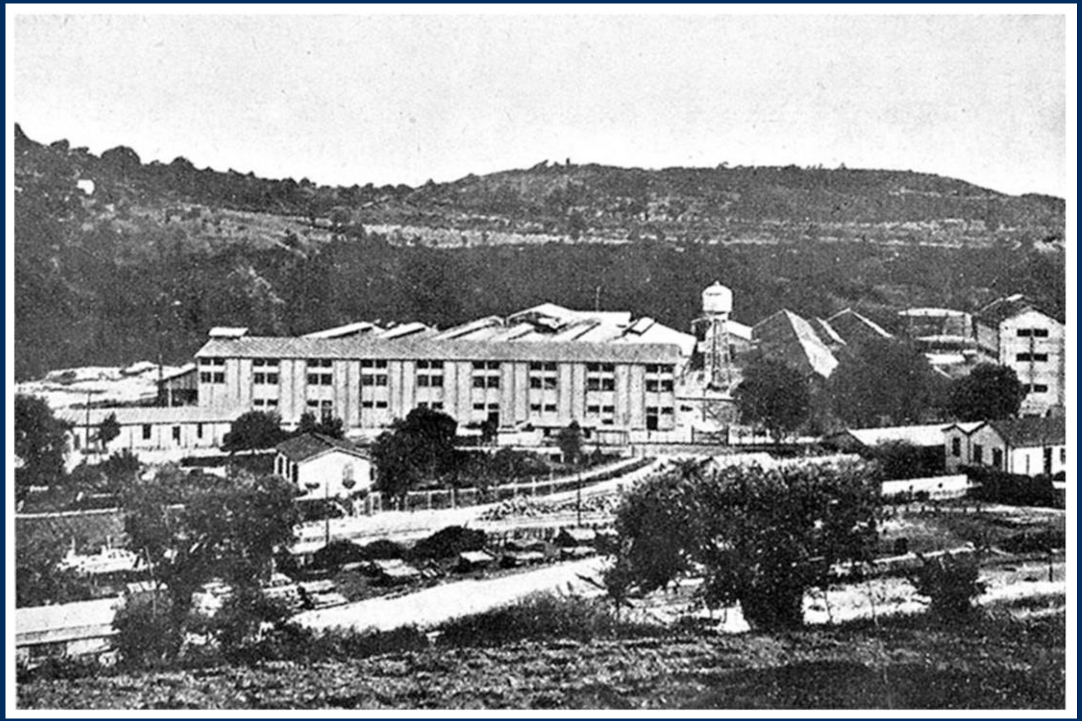
- Casale is the oldest Licensor in the green ammonia field presently in the market
- Casale built the first fully green ammonia plant about 100 years ago in Italy
- The electrolysers were fed by hydroelectric power producing hydrogen that was supplied to a dedicated synthesis loop



PFD of the ammonia synthesis loop by Casale in 1920'

Fiat car with engine fuelled with ammonia. Casale patent in 1935

CASALE GREEN AMMONIA PLANT IN 1925



Nera Montoro, Italy

Casale Water Electrolysers

CASALE

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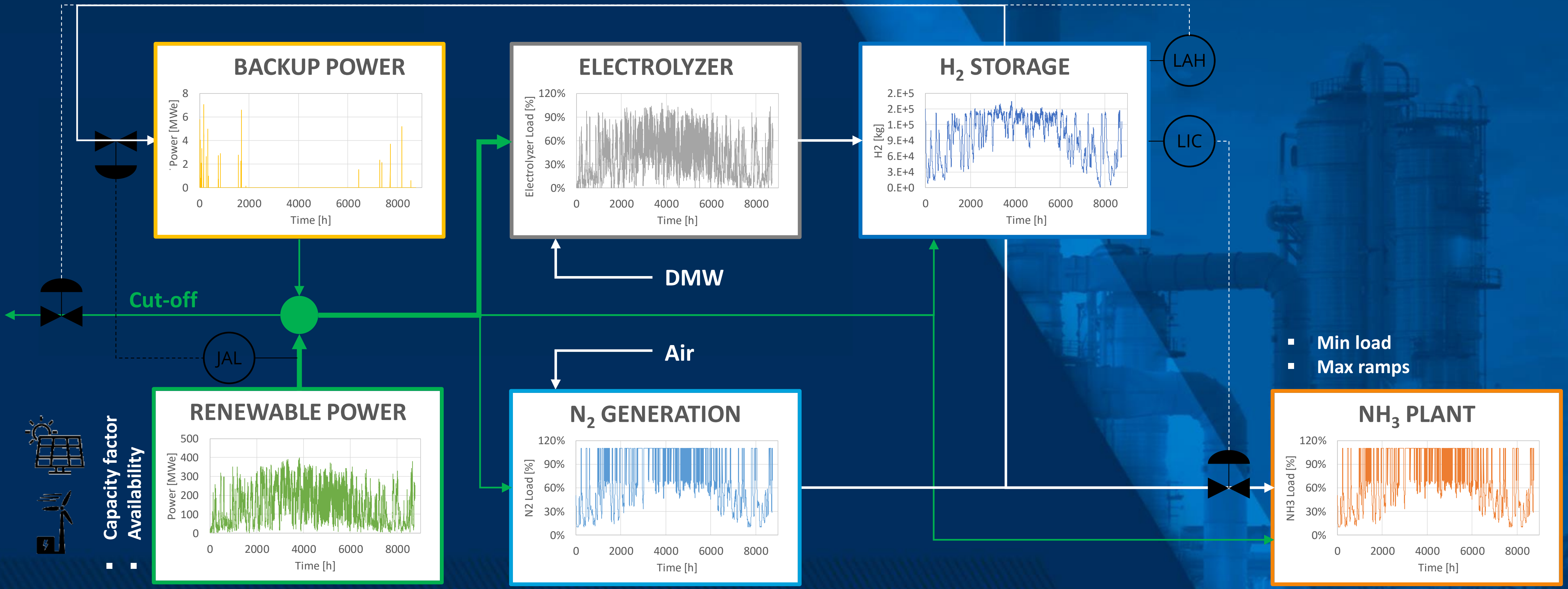
TODAY'S CHALLENGES OF GREEN AMMONIA PRODUCTION



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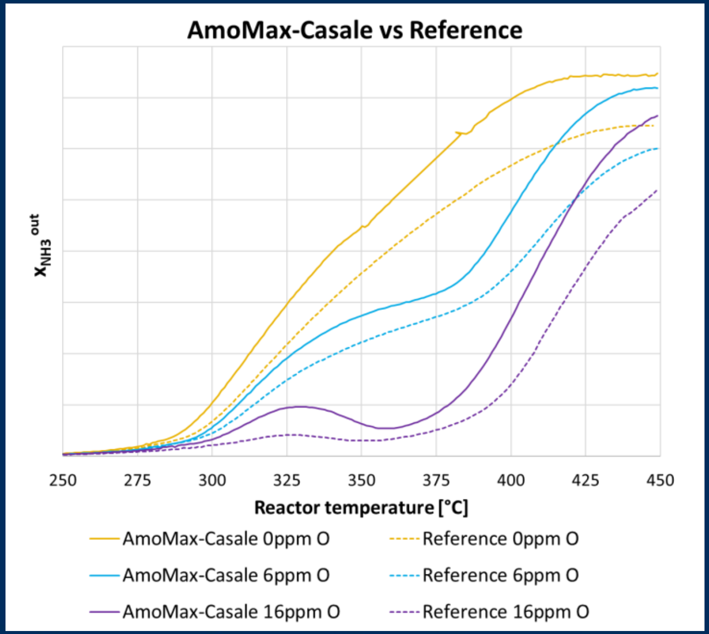
More than 300 references around the world with ZERO FAILURE rate

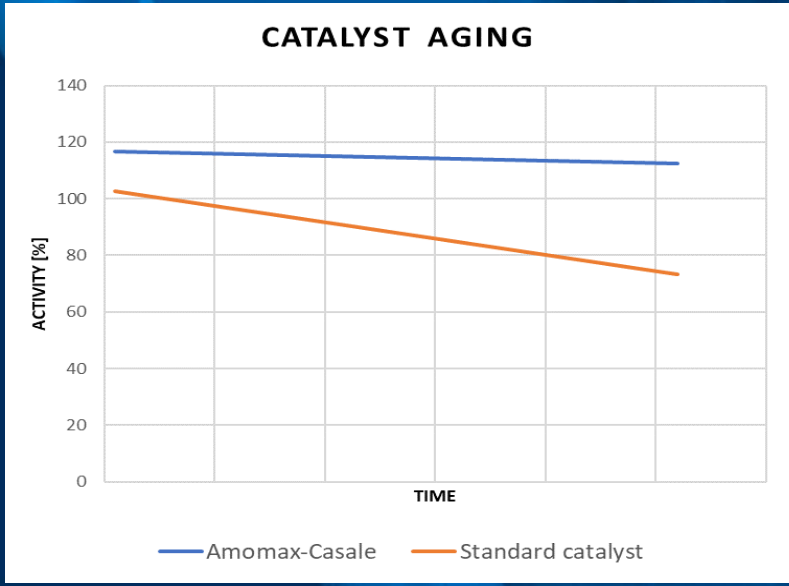
Axial Radial Converter with internal Electric Startup Heater

- High Thermodynamic Efficiency & Catalyst Volume Utilization
- Minimizing Energy Consumption
- Minimizing Loop Equipment Size
- Highest Reliability

AMOMAX CASALE TM

Jointly Developed by CASALE and CLARIANT
Amomax®-Catalyst provides high flexibility and fast response
The catalyst is **more active** at low operating temperature
Higher efficiency (+30%) and **lower consumption**





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CASALE'S 12 LOW CARBON PROJECTS

- **Skiga AS** → pre FEED for one green ammonia plant in Skipavika, Norway – 300 MTD
- **ATOME** → Basic Design for one Green ammonia loop in Villeta, Paraguay – 240 MTD
- **THE HYDROGEN UTILITY PTY LTD** → Basic Engineering Design and FEED support for **#2** Green Ammonia loop in Whylalla, South Australia – 60 MTD
- **INCITEC PIVOT LTD** → Basic Engineering Design for plant conversion from Grey to Green Ammonia in Gibson Island, Australia - 1100 MTD
- **ADVANCED METHANOL AMSTERDAM B.V.** → License, engineering, material supply and technical assistance for one new methanol plant from biomass in Amsterdam, Netherlands - 260 MTD
- **WABASH VALLEY RESOURCES LLC** → Process Design Package for new blue ammonia loop in West Terre Haute, USA – 1630 MTD

Green Ammonia Plant in Villeta, Paraguay

IPL Plant in Brisbane, Australia

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CASALE'S 12 LOW CARBON PROJECTS

- **MAE HYDROGEN LLC**→ Process Design Package for new green ammonia plant in Chile - 850 MTD
- **MACA** → Feasibility Study for new green Ammonia Plant with associated Nitric Acid, ANS and LDAN Plants in Australia – 70 MTD (Ammonia)
- **METAFRAX** → New Ammonia loop from methanol plant off-gases in Gubakha, Russia – 1000 MTD
- **CONFIDENTIAL** → Feasibility Study for new green ammonia loop – 50 MTD
- **CONFIDENTIAL** → Basic Engineering Desgn for new green ammonia loop – 750 MTD

Green Ammonia Plant in Villeta, Paraguay

IPL Plant in Brisbane, Australia

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Thanks for your attention
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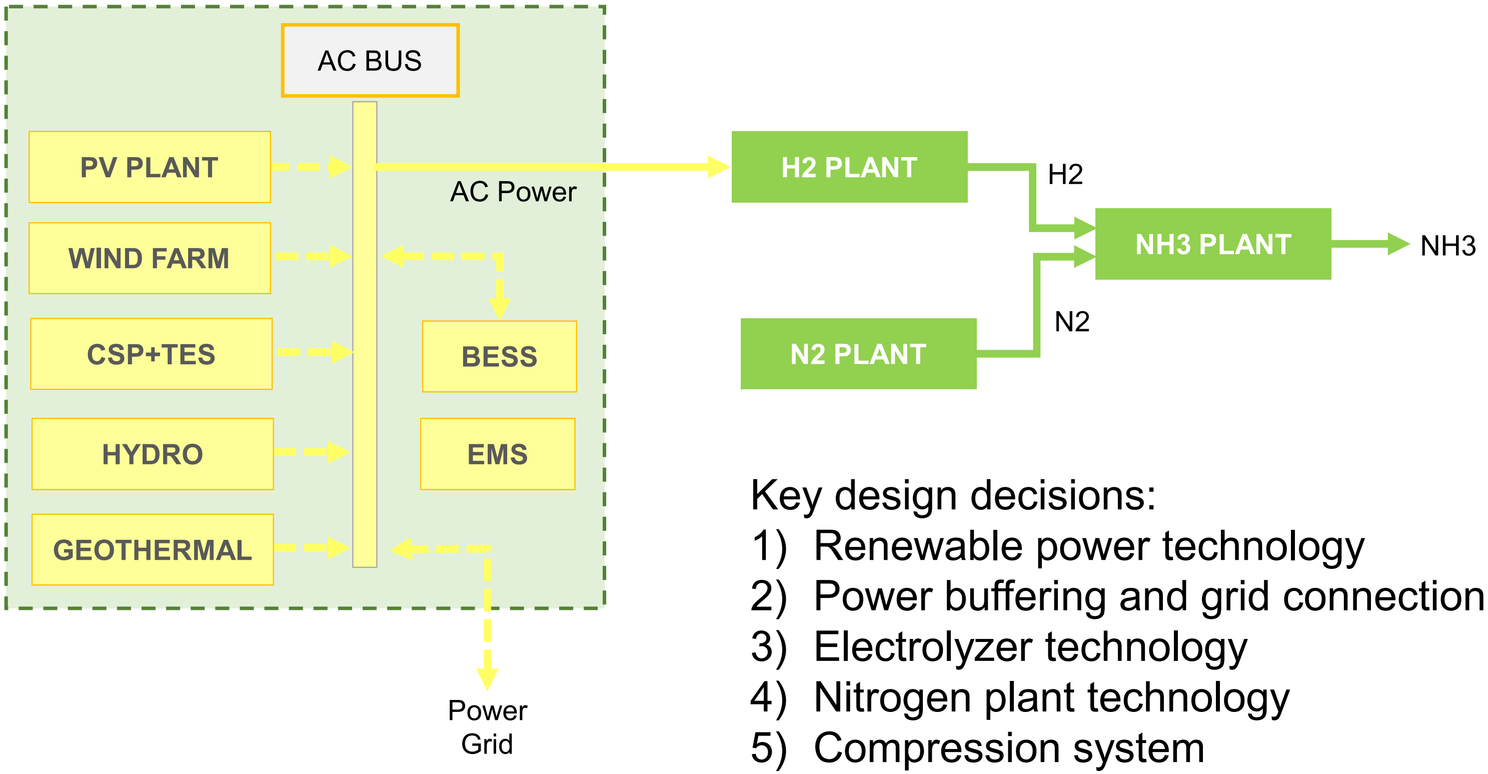
Renewable NH3 Plants
Basic design technical aspects

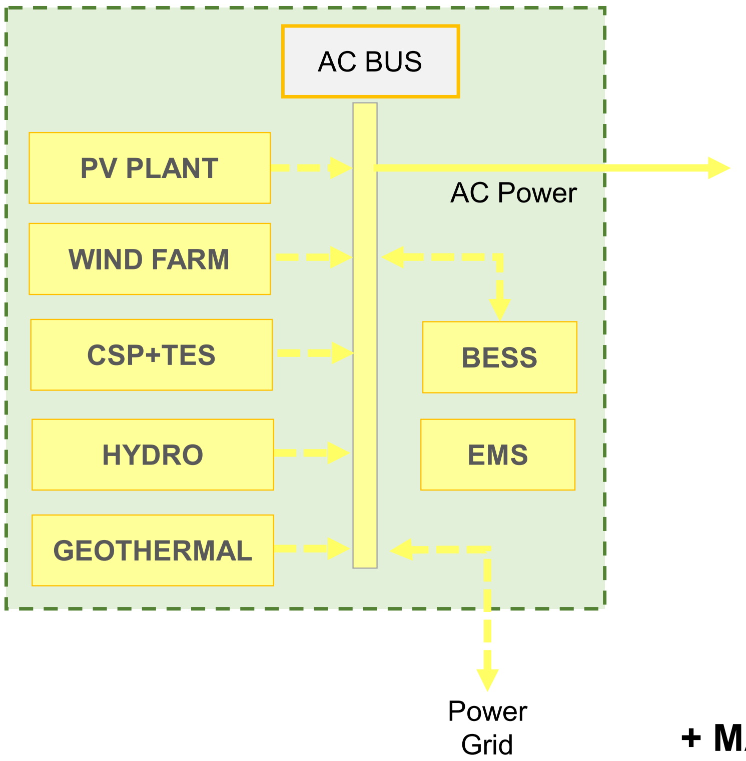
1. Simplified Renewable NH3 plant block diagram

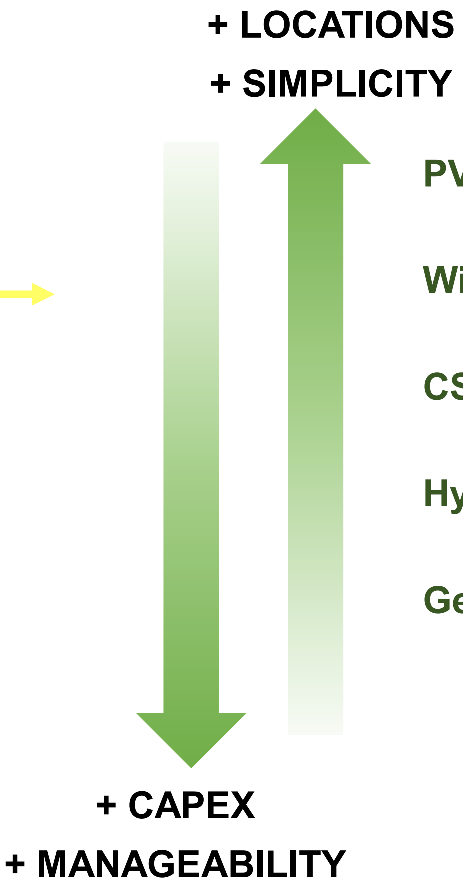


Key design decisions:

1) Renewable power technology
2) Power buffering and grid connection
3) Electrolyzer technology
4) Nitrogen plant technology
5) Compression system
6) NH3 licensor
7) BOP design, water issues, internal buffers

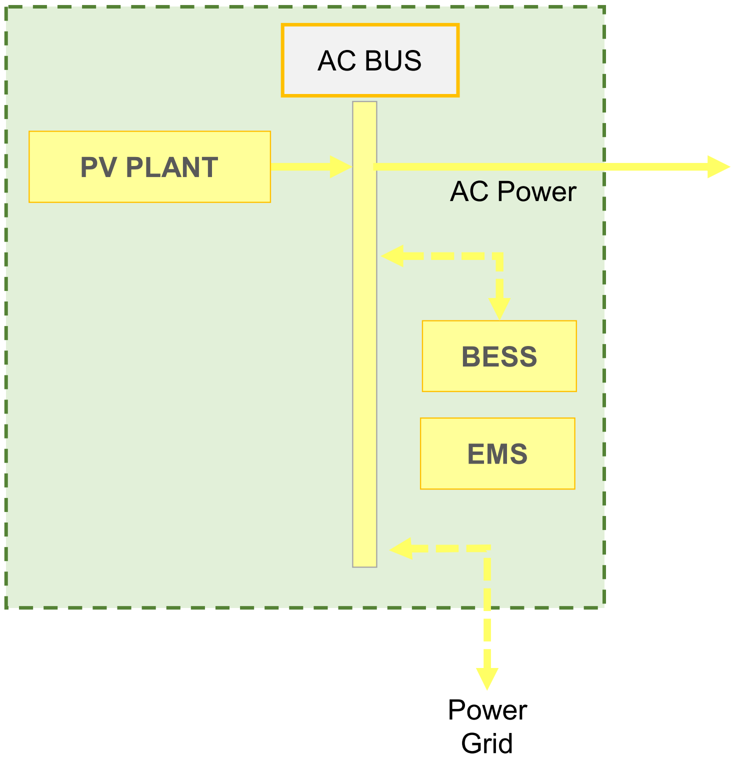
2. The Renewable Power Supply selection





PV	Fluctuant. Partially predictable. Equivalent hours: 1500~2500 h
Wind	Fluctuant. Not predictable. Equivalent hours: 2000~3500 h
CSP+TES	Fluctuant. Predictable. Equivalent hours: >4000 h
Hydro	Constant. Predictable. Equivalent hours >5000 h
Geothermal	Constant. Predictable. Equivalent hours >8000 h

2. The Renewable Power Supply. PV (I)



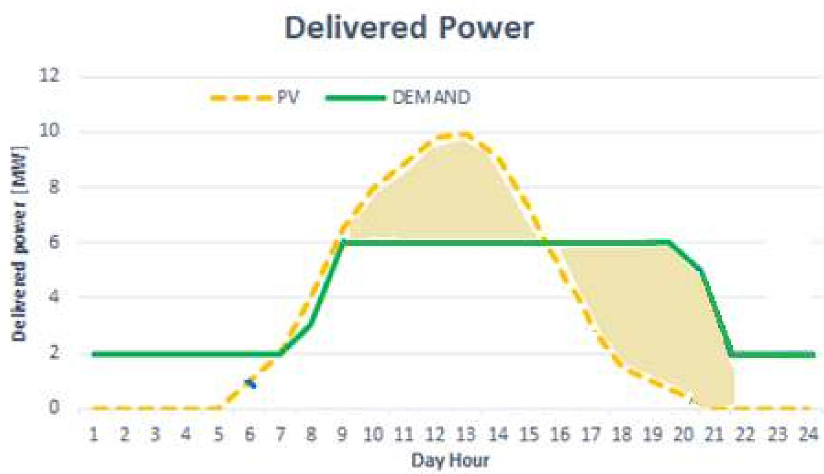
Probably the most common in worldwide developments.

PROS Lowest CAPEX of all renewables.
Reduced project development time.

CONS Not predictable.
Fast fluctuations

Dynamics need to be satisfied. Solutions:

a) BESS → will increase the CAPEX
b) Grid connection for stability → loosing the green label? PPA cost?



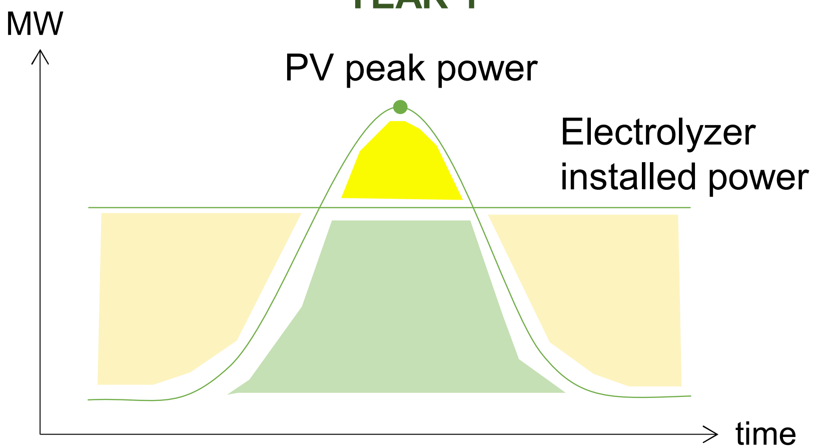
2. The Renewable Power Supply. PV (II)

What size of PV vs Electrolyzers?

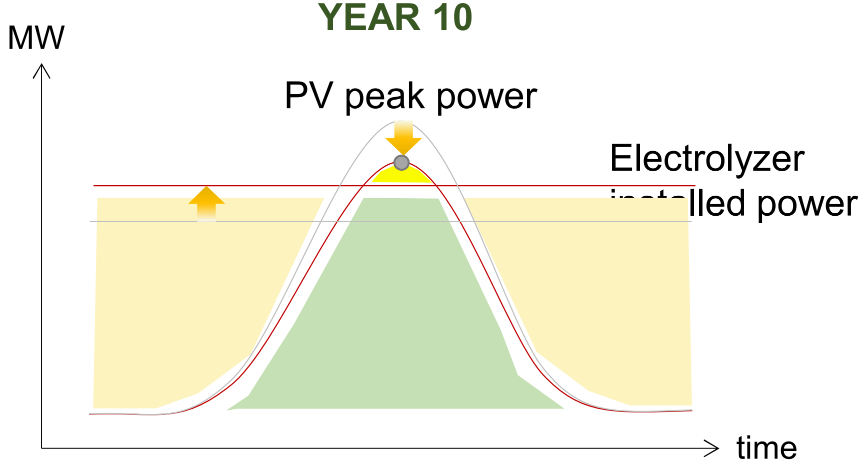
PV degradation	0.3% ~ 0.5% per year Loss in power production
Electrolyzers degradation	1.0% ~ 1.5% per year Extra power demand for same H2 output

- (yellow) PV power > H2power. PV plant infra-used (surplus power)
- (light yellow) H2 Power > PV Power. H2 plant infra-used
- (green) Used power for H2/NH3 production; typically <40% of installed capacity

YEAR 1

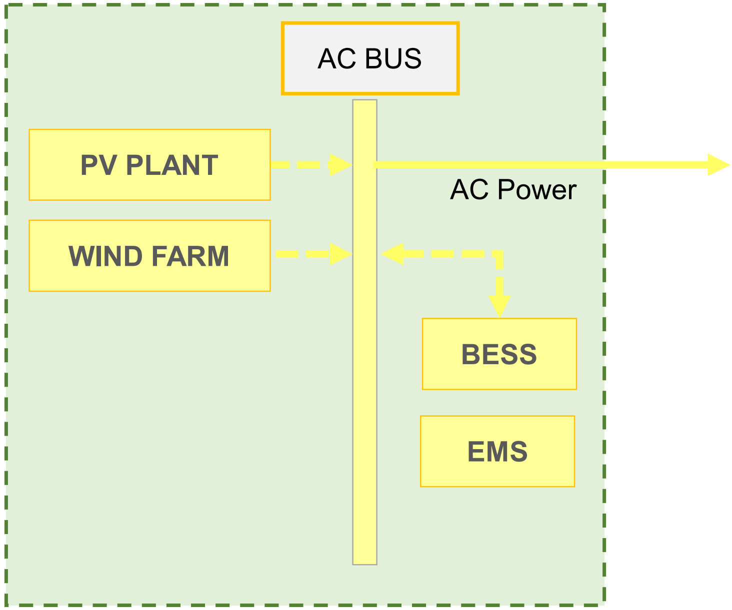


YEAR 10



Optimum point between 1.2 and 2.0 PV_power/H2_power
To be analyzed case by case, depending on PV capacity factor, PV cost, H2 cost, and other paramaters

2. The Renewable Power Supply.
PV-Wind Hybridation



Improves the availability of stand alone PV or Wind.

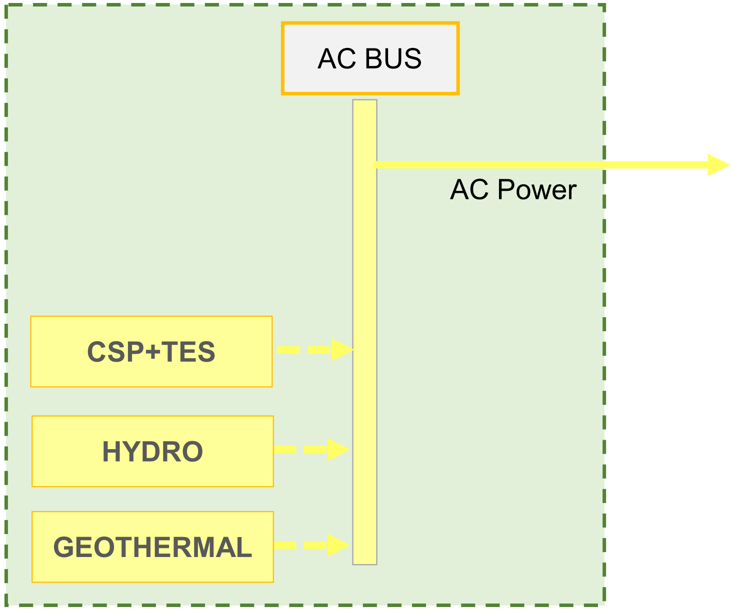
PROS Increases the H2 capacity factor to >50%

CONS High CAPEX
System design difficulties
Still produce surplus power

Optimum point to be analyzed case by case.
Example results from real feasibility studies:

50 MW PV + 50 MW Wind + 50 MW H2/NH3
75 MW PV + 125 MW Wind + 125 MW H2/NH3

2. The Renewable Power Supply.
Hydro, Geothermal or CSP



Manageable and stable power supply.

PROS	Increases the H2 capacity factor to >90% System simplicity (no hybridation, no BESS) Best LCOH results (Levelized cost of hydrogen)
CONS	High CAPEX (specially for CSP) Lack of locations and resources (hydro and geo) Developers typically prefer to sell energy rather to produce H2/NH3 in this kind of plants

Typically, same capacity in power and electrolyzer plants.
Some gap to prevent degradation could be considered.

Example cases:

- 120 MW Hydro + 120 MW H2/NH3
- 50 MW Geothermal + 48 MW H2/NH3

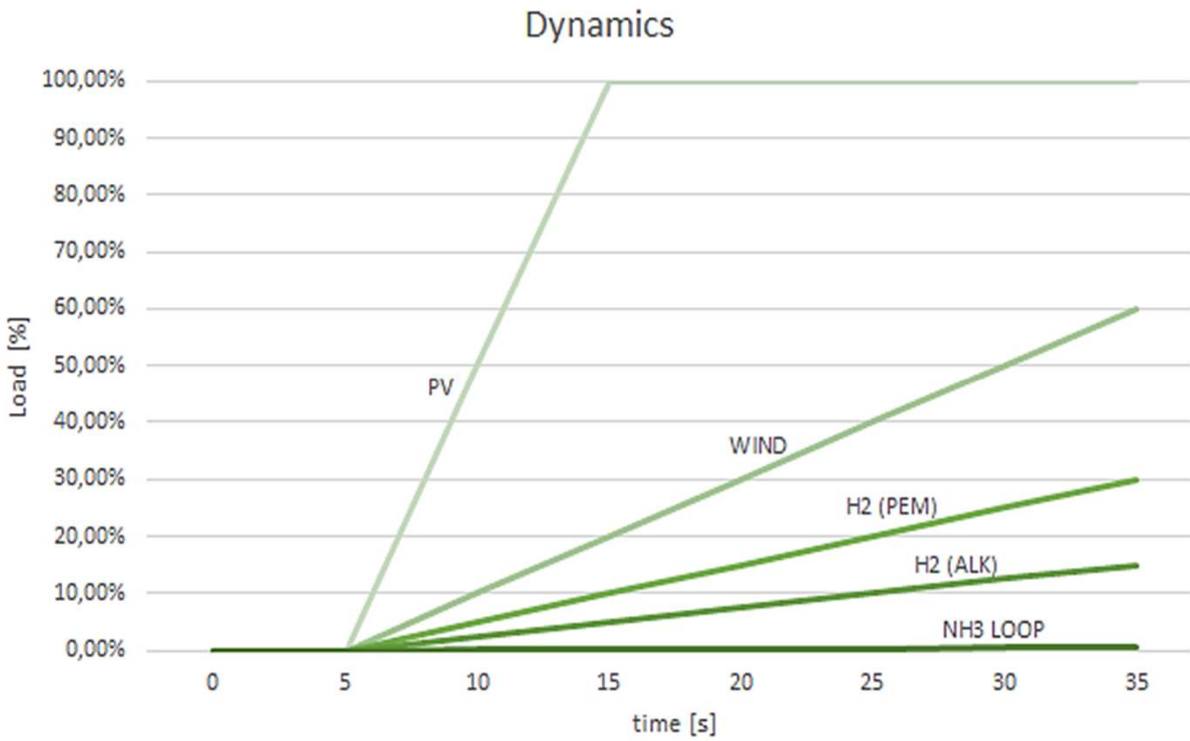
3. The electrolyzer selection

Key parameters driving the selection process, together with the selected renewable power plant and the NH3 plant load demand,

		ALKALINE		PEM		SOEC
Presurizad		Yes	No	Yes	No	Yes
Efficiency (stack level)	kWh/kg	54-56	54-56	50-54	50-54	<50
Efficiency (plant level)	kWh/kg	57-60	58-62	53-57	54-59	<53
CAPEX	€/kW	1000-1500	1000-1500	1500-2000	1500-2000	>2000
OPEX	€/kW/year	25-50	25-50	50-100	50-100	
Load falling	%/sec	0,5%	0,5%	1%	1%	>1%
Degradation	%/year	1%	1%	1%-2%	1%-2%	
Footprint restrictions		Yes	Yes	No	No	No
Manufacturing capacity		High	High	Medium	Medium	Low
Maturity		High	High	Medium	Medium	Low

4. Ammonia licensor selection.
The dynamics problem with PV and Wind

H2 PLANT	1% per second (PEM) 0,5% per second (ALK)
NH3 PLANT	1% per minute (best in-class by Casale)
PV PLANT	Not manageable changes at <u>millisecond level</u>
WIND FARM	Not manageable changes at <u>second level</u>



Energy storage and H2 buffering is typically needed to integrate the different dynamics.
Fast load following NH3 plants will reduce the buffering needs.

5. Integrating H_2 and NH_3 plants.
Hydro-power case

Key design decisions (I)

1) Electrolyzer technology

   ALK: lower CAPEX/OPEX
   PEM: higher efficiency
   SOEC: not mature, not recommended
   Selection case by case
   cost of H_2 (LCOH) in the business model is critical

2) Air Separation unit technology

   PSA: small plants
   Cryogenic: large plants

3) Ammonia technology

   Haber-Bosch licensor to be selected depending on,
   the licensor's reactor sizing and efficiency,
   the licensor improvements on integrating green hydrogen.

5. Integrating H_2 and NH_3 plants. Hydro-power case

Key design decisions (II)

4) Pressure integration

Typical H_2 production pressure: 1 to 30 bar
Typical N_2 production pressure: 5 to 6 bar
Typical NH_3 loop working pressure: 200 bar
Optimization is needed to reduce the number of dedicated compressors. A final syngas (H_2+N_2) compressor is needed to increase the pressure up to 200 bar.

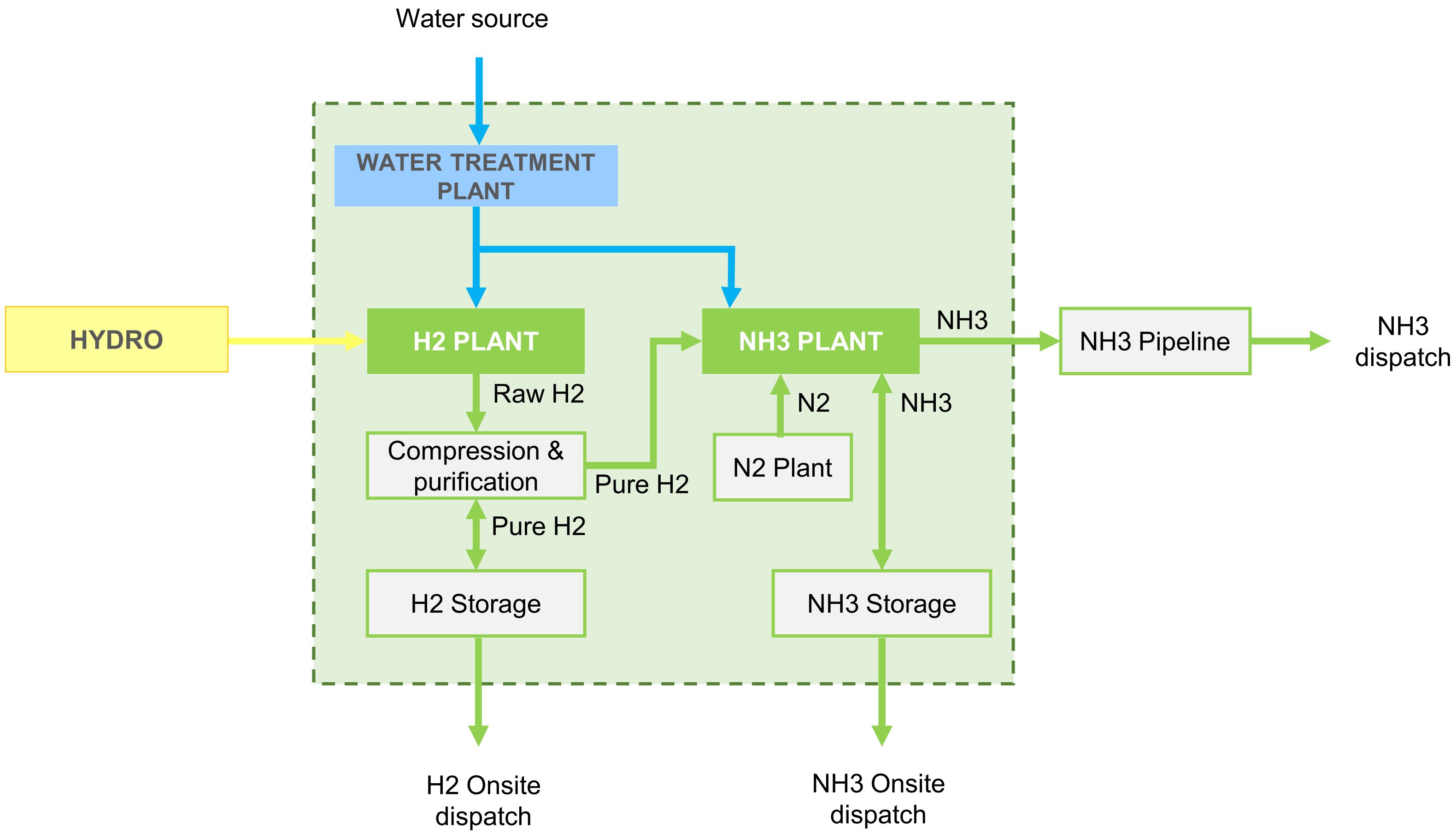
5) Buffering

H_2 and N_2 buffers typically foreseen to assure a constant supply of syngas to the NH_3 loop.

5) Water availability

Will determine the water treatment system and the cooling system. If possible, low conductivity water and cooling tower are typically preferred.

5. Integrating H2 and NH3 plants.
Hydro-power case. Plant design result



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