Ammonia-blends for gas turbines

Agustin Valera-Medina

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SMART ENERGY FOR OUR FUTURE
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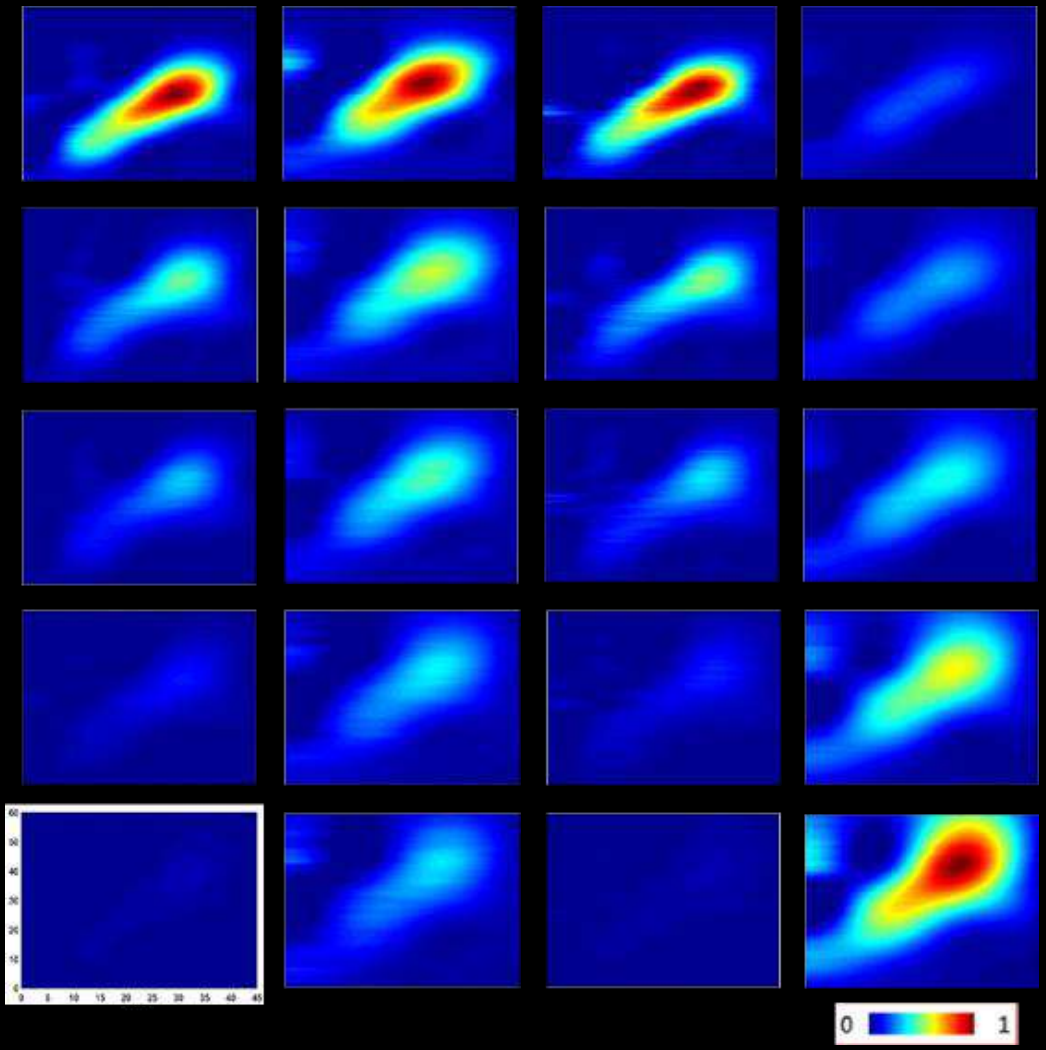


INTRODUCTION

- Renewables are one of the best technologies to provide the needed energy whilst reducing greenhouse gases.
- The problem is their intermittency (i.e. Australia - 2 weeks Blackout; UK – 1 Million People during ~48% Wind power).
- However, their intermittent nature requires the use of energy storage (batteries, chemicals, compressed gas, etc.)

HYDROGEN AND AMMONIA

Exhibit 11: Distribution of global hydrogen resources and demand centers

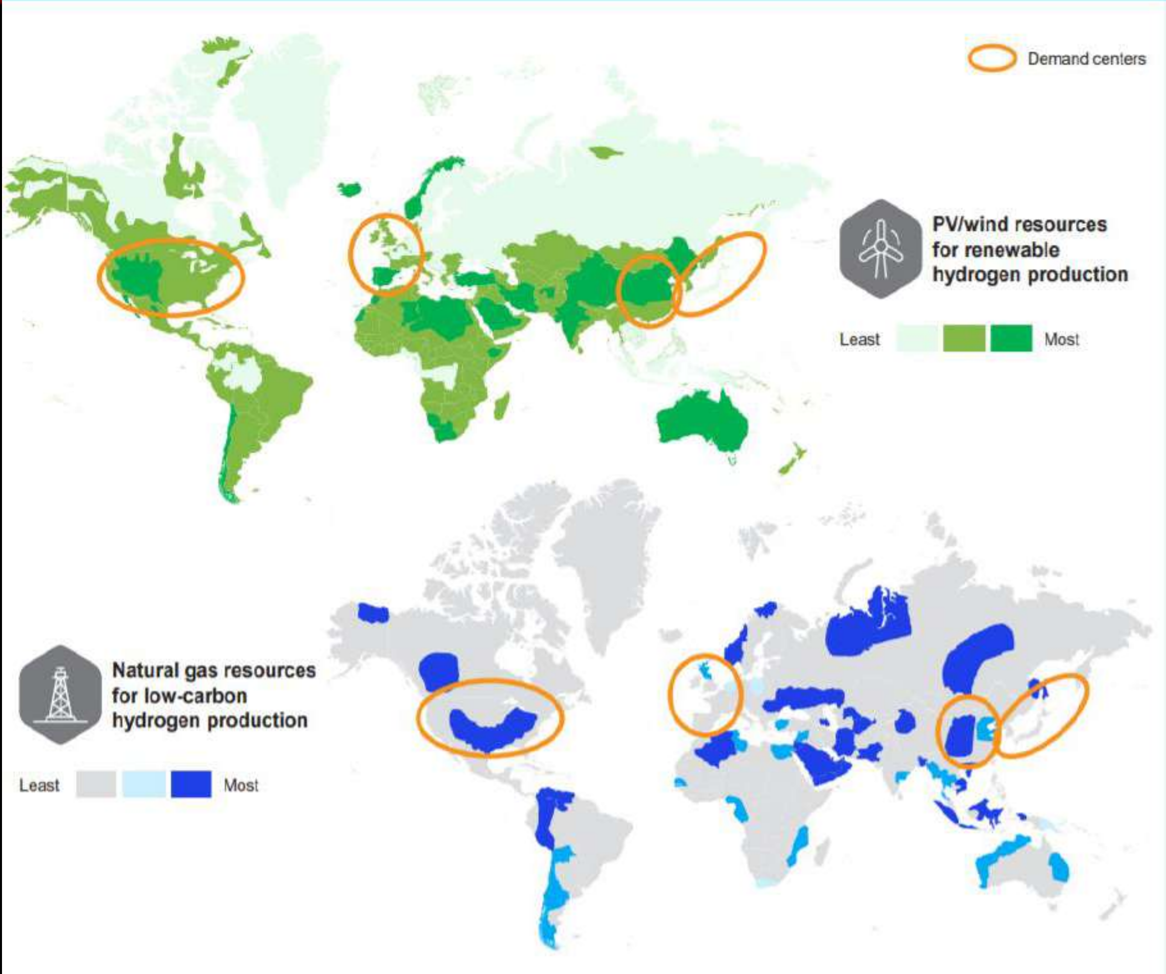
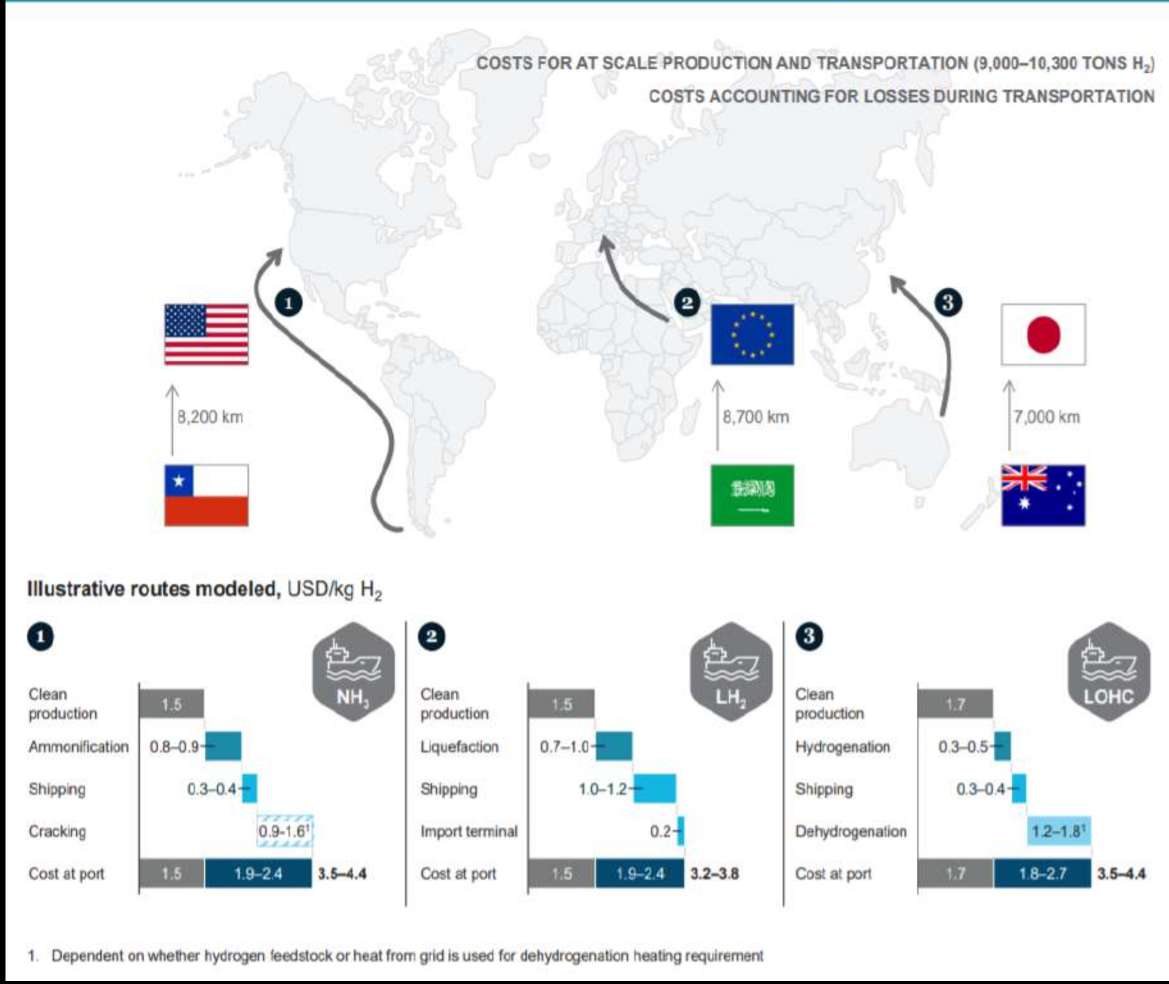


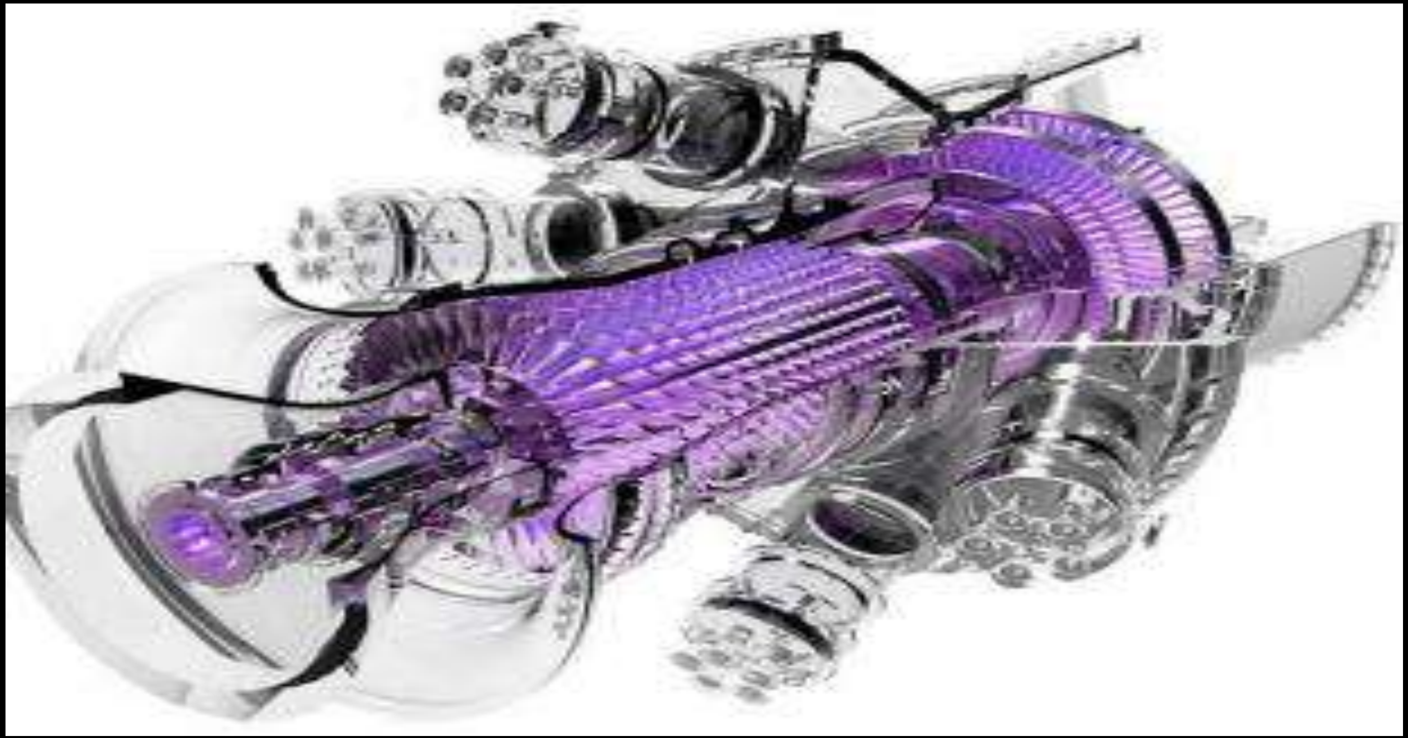
Exhibit 16: Landed costs of hydrogen at port for selected global transport routes



Hydrogen Distribution and comparison between vectors [Hydrogen Council 2021]

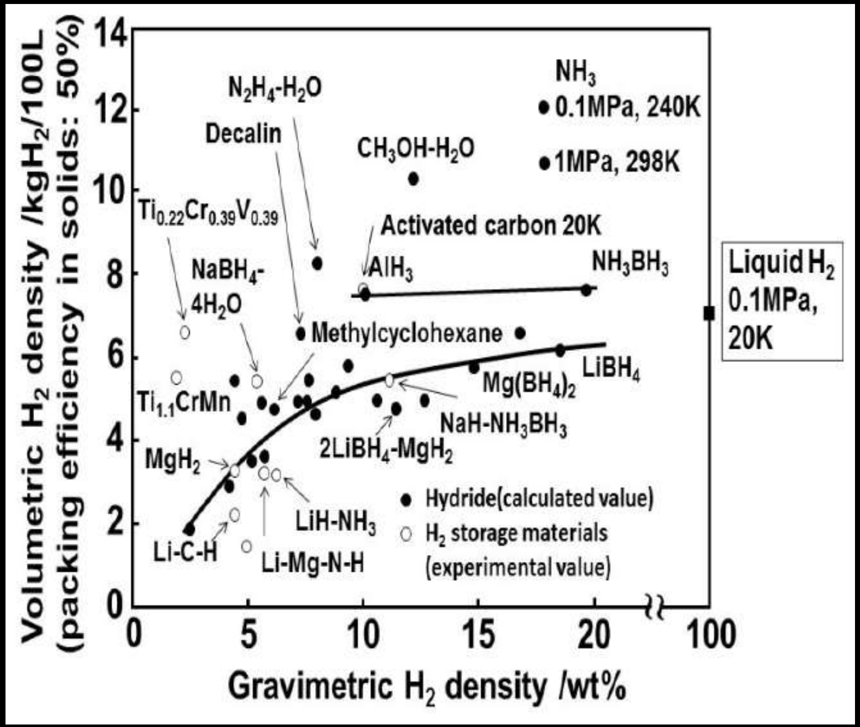
HYDROGEN AND AMMONIA

- However, hydrogen transportation and storage is a challenge.
- Moreover, hydrogen explosive nature combined with fast reactivity have always been a problem for developers to obtain large energy quantities.
- Therefore, another chemical with high hydrogen content can be used.

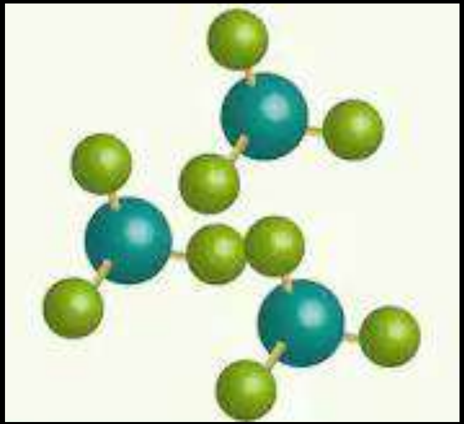


HYDROGEN AND AMMONIA

- Ammonia can
  - be obtained from renewable sources,
  - allow the rescue of stranded resources,
  - enables the use of waste streams,
  - allow storage of vast amounts of energy 30 times cheaper than H2,
  - be used to produce energy in Islands or isolated regions,
  - be used as a fuel, but also as a fertilizer,
  - High hydrogen content (higher than liquid H2),
  - have a great economical potential, with a market size up to 184 Billion Euros per year.

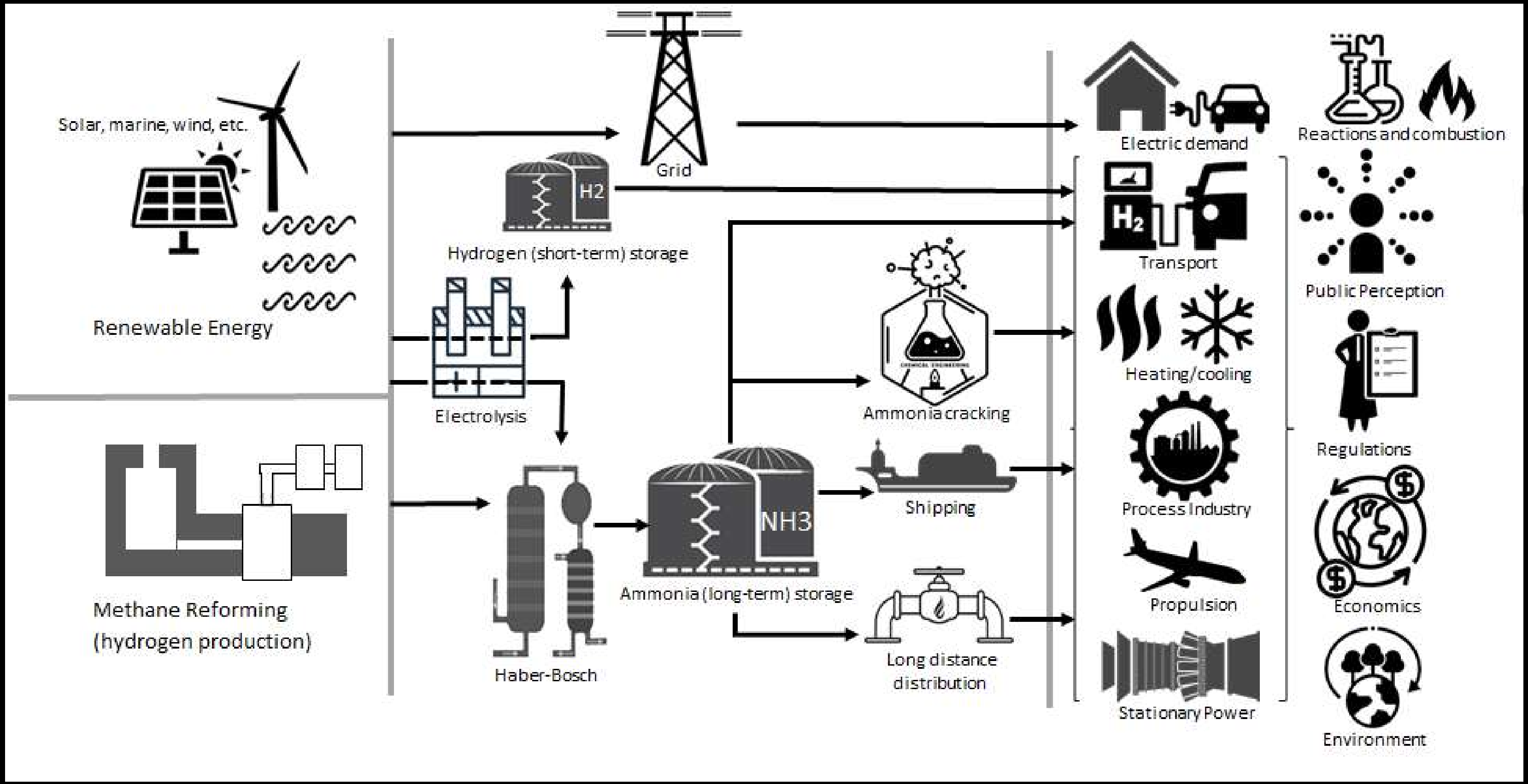


Hydrogen densities in hydrogen carriers. Courtesy of Prof. Yoshitsugu Kojima, Hiroshima University.



HYDROGEN AND AMMONIA

- Although ammonia combustion is still seen as the lowest end of the use of ammonia for energy, cheaper distribution, higher hydrogen content and easier operation will change the position of NH3 in the energy arena.



Green Ammonia/Hydrogen Economy [Valera-Medina and Banares-Alcantara, 2020]

HYDROGEN AND AMMONIA

World's largest renewable energy project proposed for north-west Australia ditches electricity in favour of ammonia exports

ABC Kimberley / By Ben Collins and Vanessa Mills

Posted Yesterday at 3:29am, updated Yesterday at 3:59am

The proposal is to use large-scale wind and solar electricity to p

Air Products announce $5 billion renewable hydrogen to ammonia project in Saudi Arabia

DATE POSTED: 16TH AUG 2020

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POST AUTHOR

Philip Sharm

IFRF DIRECTOR

HYDROGEN POWER

CF plans green ammonia plant in Louisiana

The company believes it can make more money in hydrogen than it does in fertilizer

by Alexander H. Tullo

NOVEMBER 5, 2020 | APPEARED IN VOLUME 98, ISSUE 43

Credit: CF Industries

CF Industries' fertilizer plant in Donaldsonville, Louisiana

MOST POPULAR IN ENERGY

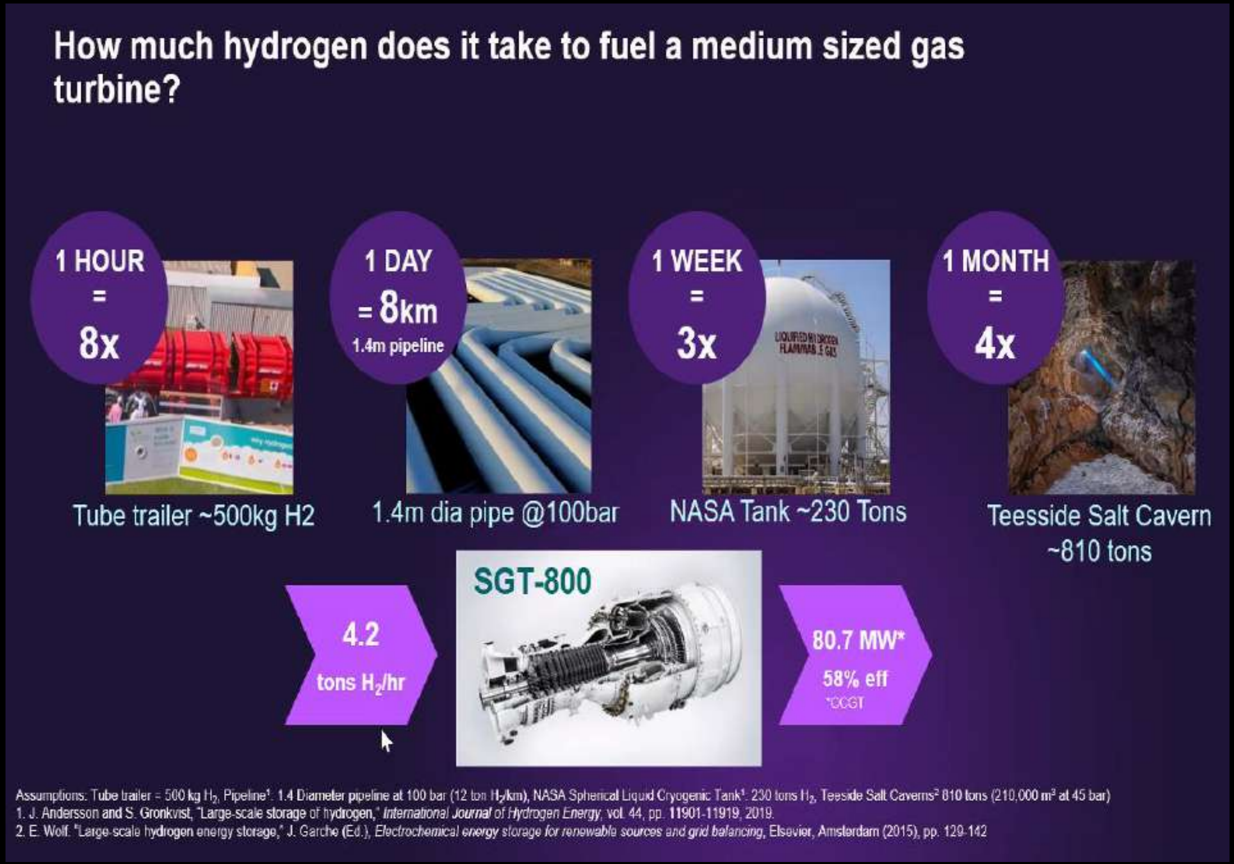
- CF plans green ammonia plant in Louisiana
- Solid-state batteries power up
- Nuclear Power Prevents More Deaths Than It Causes
- Combating corrosion in the world's aging nuclear reactors

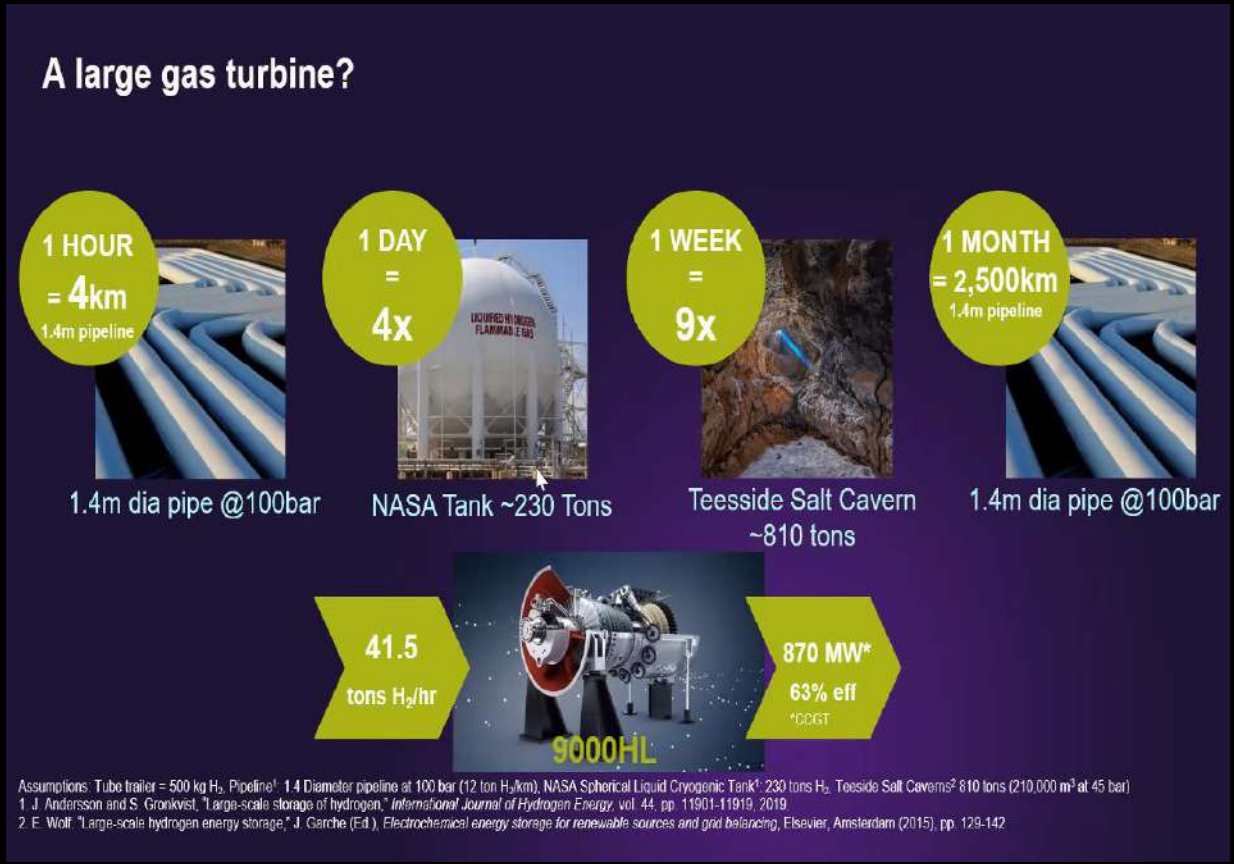
CHALLENGES

However, the technology faces the following obstacles,

1. Ammonia Carbon-free synthesis (cost reduction, efficiency improvement)
2. **Power generation at utility-scale from ammonia production (stable, low emissions)**
3. **Public acceptance through safe regulations and appropriate community engagement.**
4. Economics – profitable scenarios (cannot be applied everywhere)

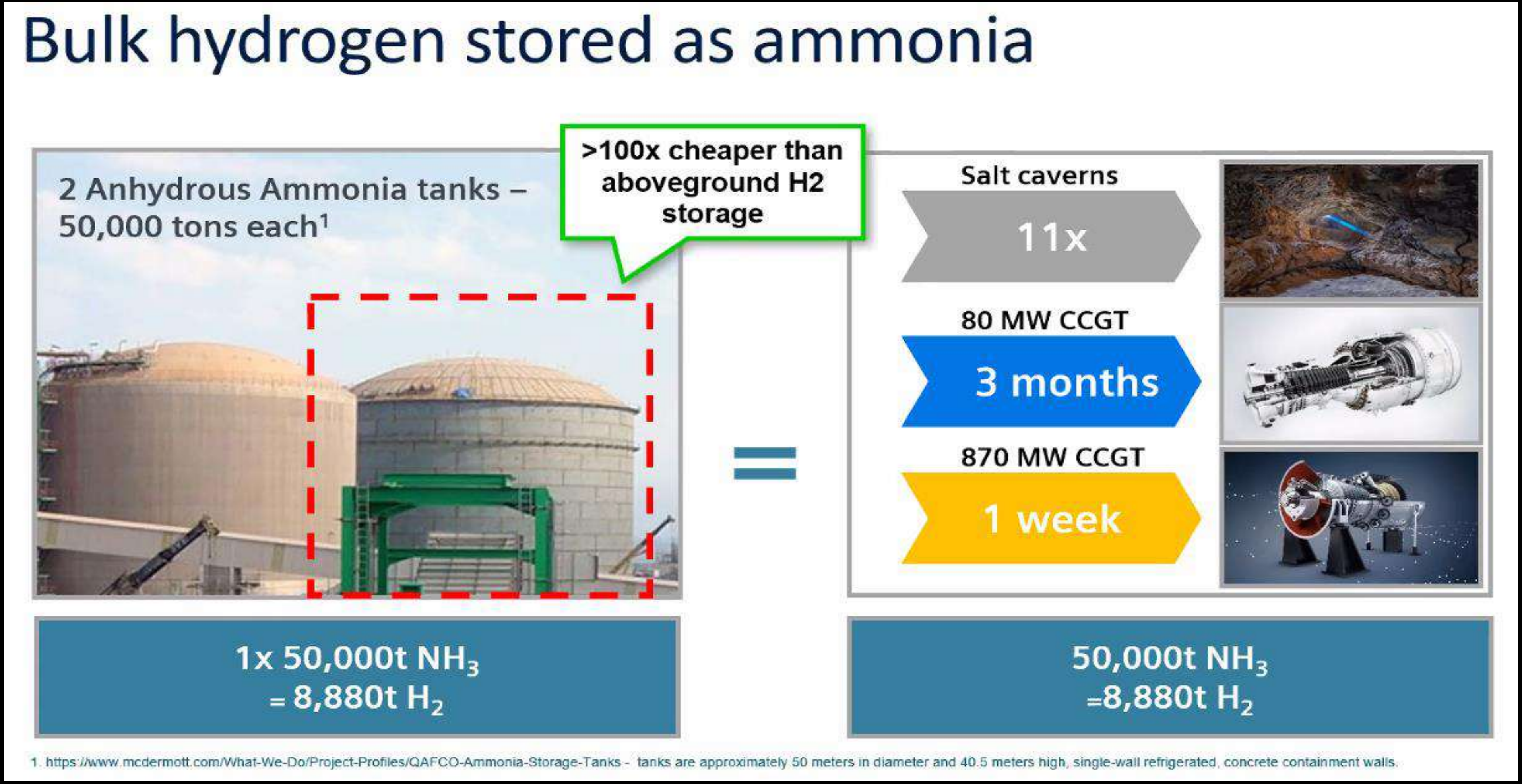
DEVELOPMENTS- AMMONIA GAS TURBINES





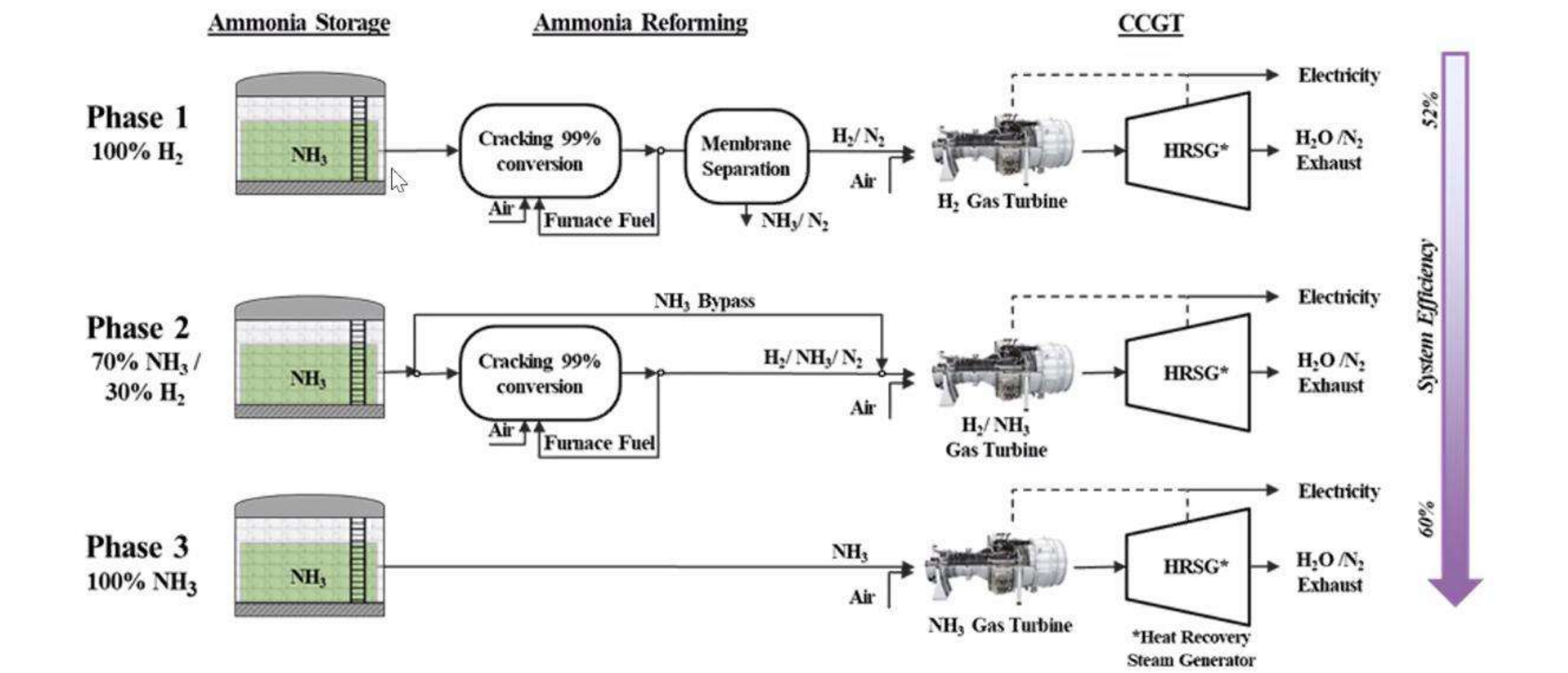
Hydrogen requirements for two different sized gas turbines [Cesar Z, UK-India Ammonia meeting, 2020**]**

DEVELOPMENTS- AMMONIA GAS TURBINES



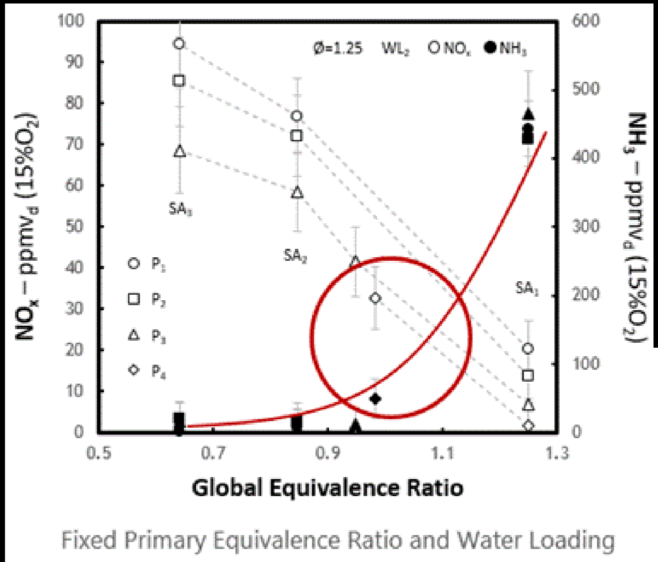
Hydrogen requirements for two different sized gas turbines [Cesar Z, UK-India Ammonia meeting, 2020**]**

DEVELOPMENTS- AMMONIA GAS TURBINES

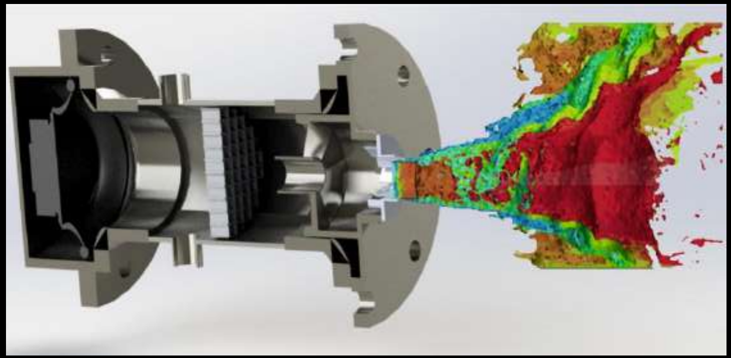


Efficiency of conversion of energy from ammonia in gas turbines [Cesaro Z, et al. Applied Energy, 2020**]**

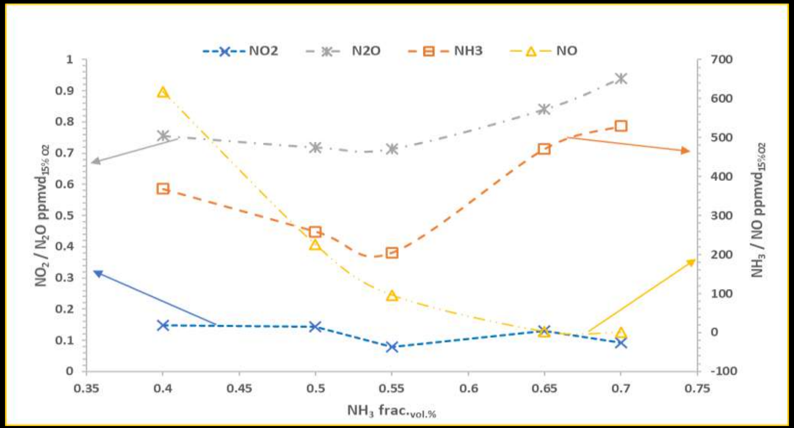
DEVELOPMENTS- AMMONIA GAS TURBINES

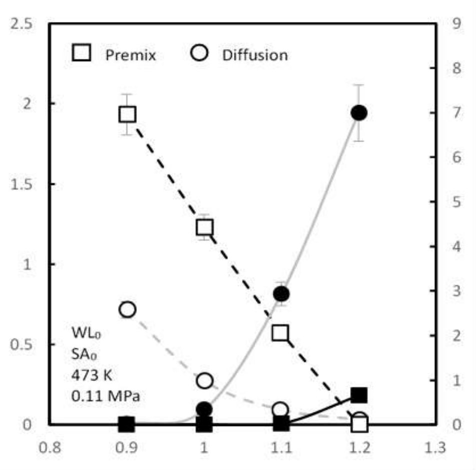


Secondary Air (SA) addition with steam injection. Cardiff University [Pugh et al, 2018]

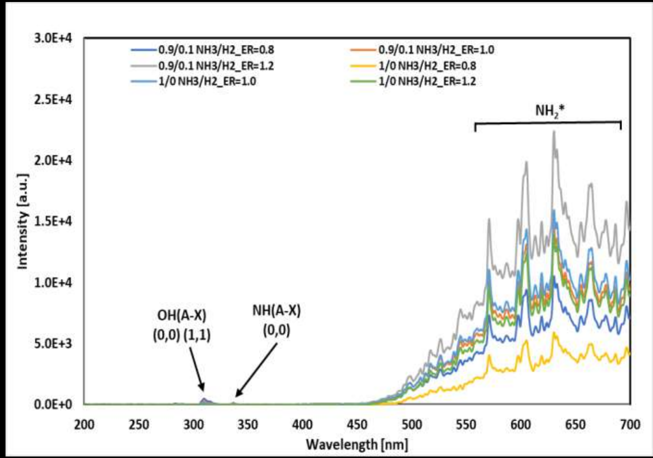


Modelling[Vigueras et al, 2020]

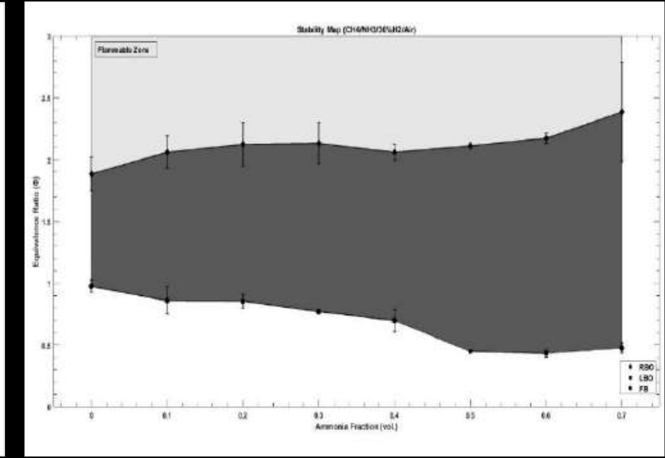




Different injection methods [Pugh et al, 2020]

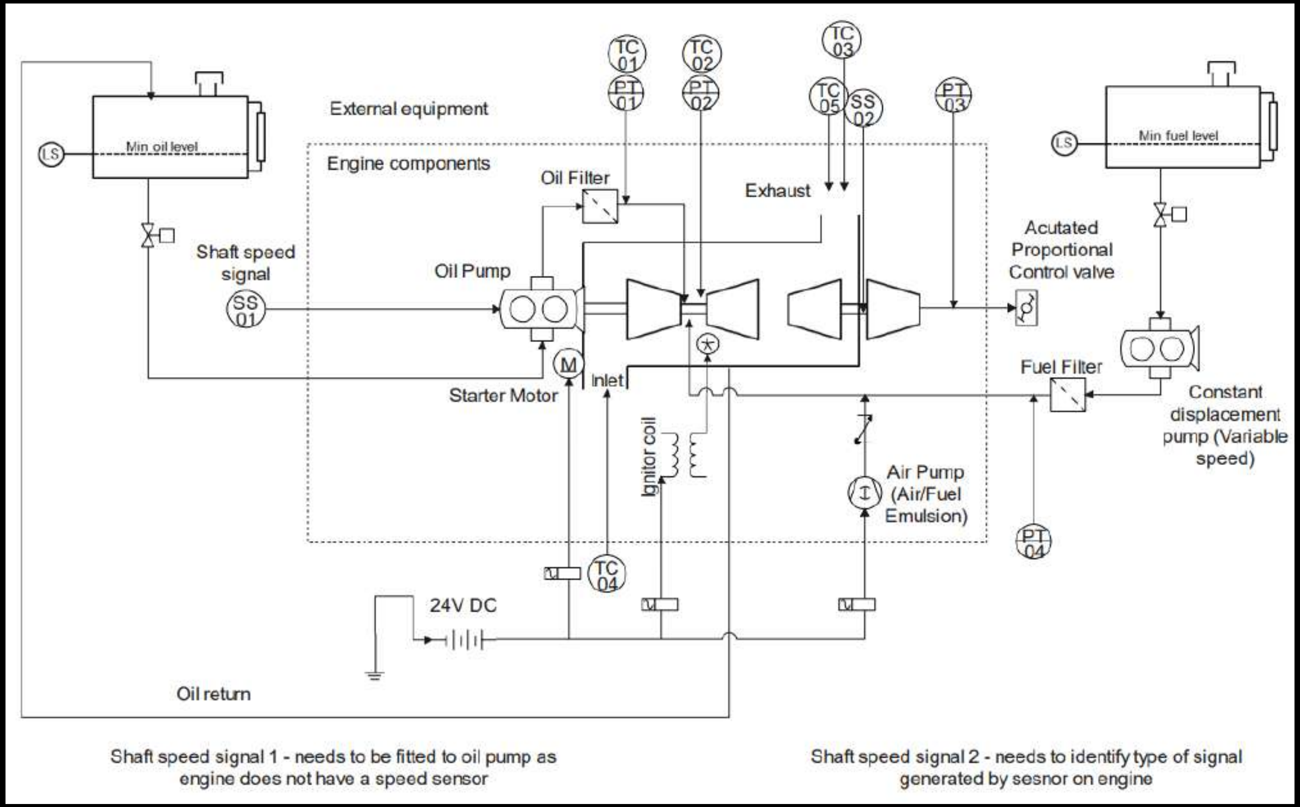


Spectral analyses

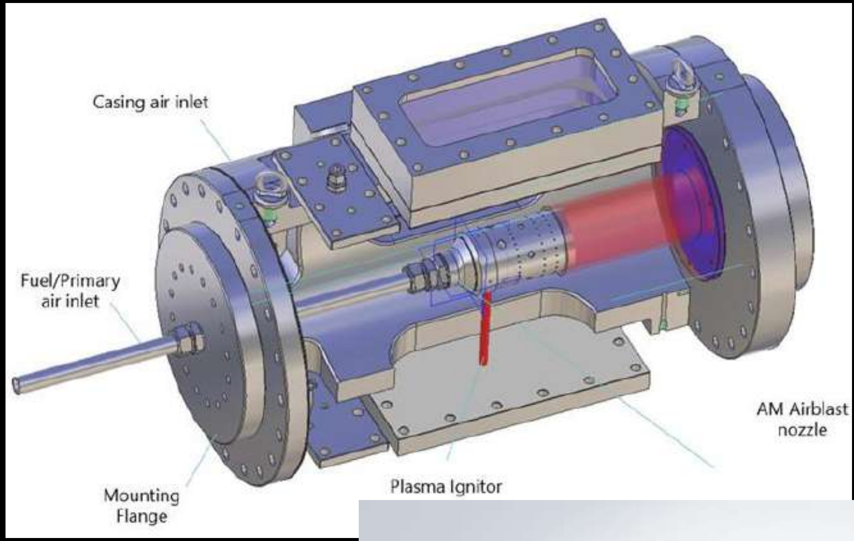


Emissions and Stability Maps [Under review, IJHE 2021**]**

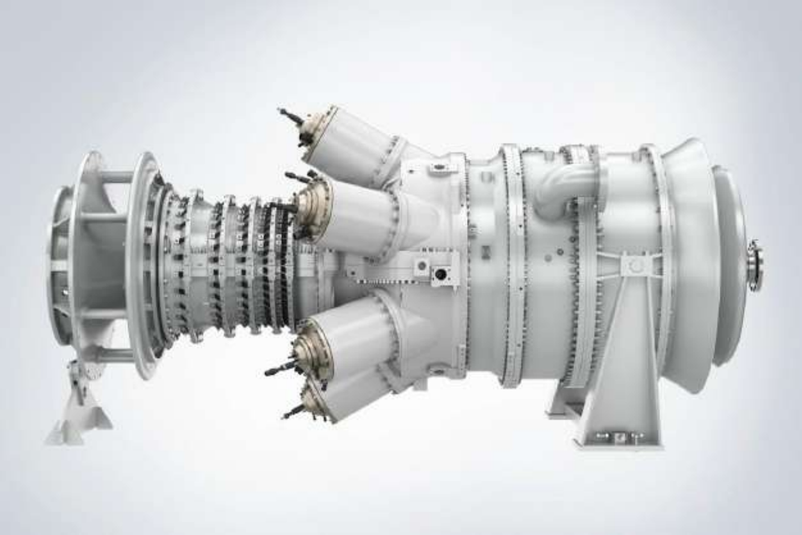
DEVELOPMENTS- AMMONIA GAS TURBINES



APU Diagram for retrofitting and control development.

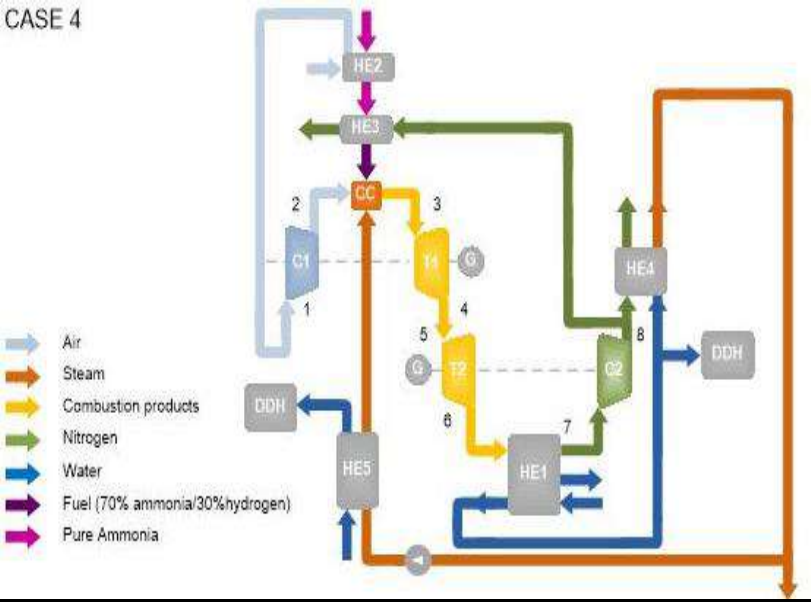


Results and a new design will be evaluated for a Siemens SGT-400 unit.



DEVELOPMENTS- AMMONIA GAS TURBINES

- Now, research is focused on ultra-low NOx combined with high efficiencies and power outputs.



Modified Brayton Cycle

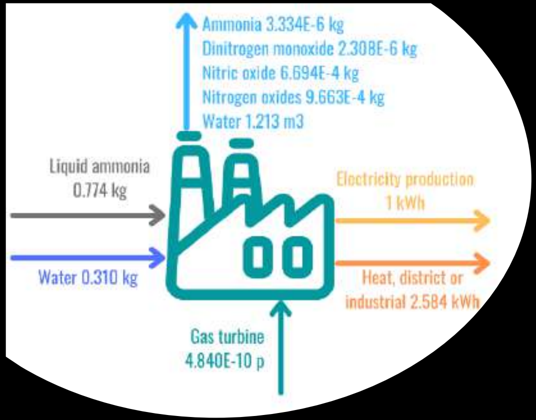
Inlet temperature 1260K

Outlet temperature 827K

Supplied heat 10.45MWth

Power 3.56MWe

Plant efficiency 34%

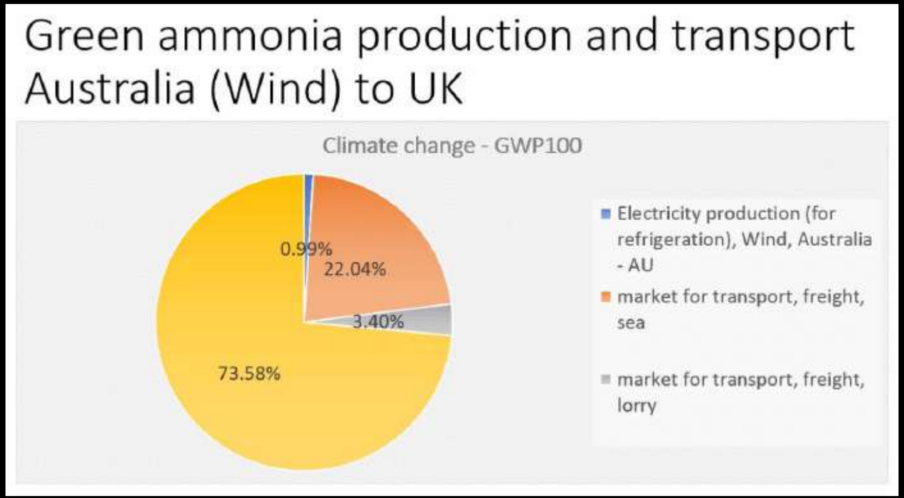


Trigeneration Cycle

Cooling+Power+Heating

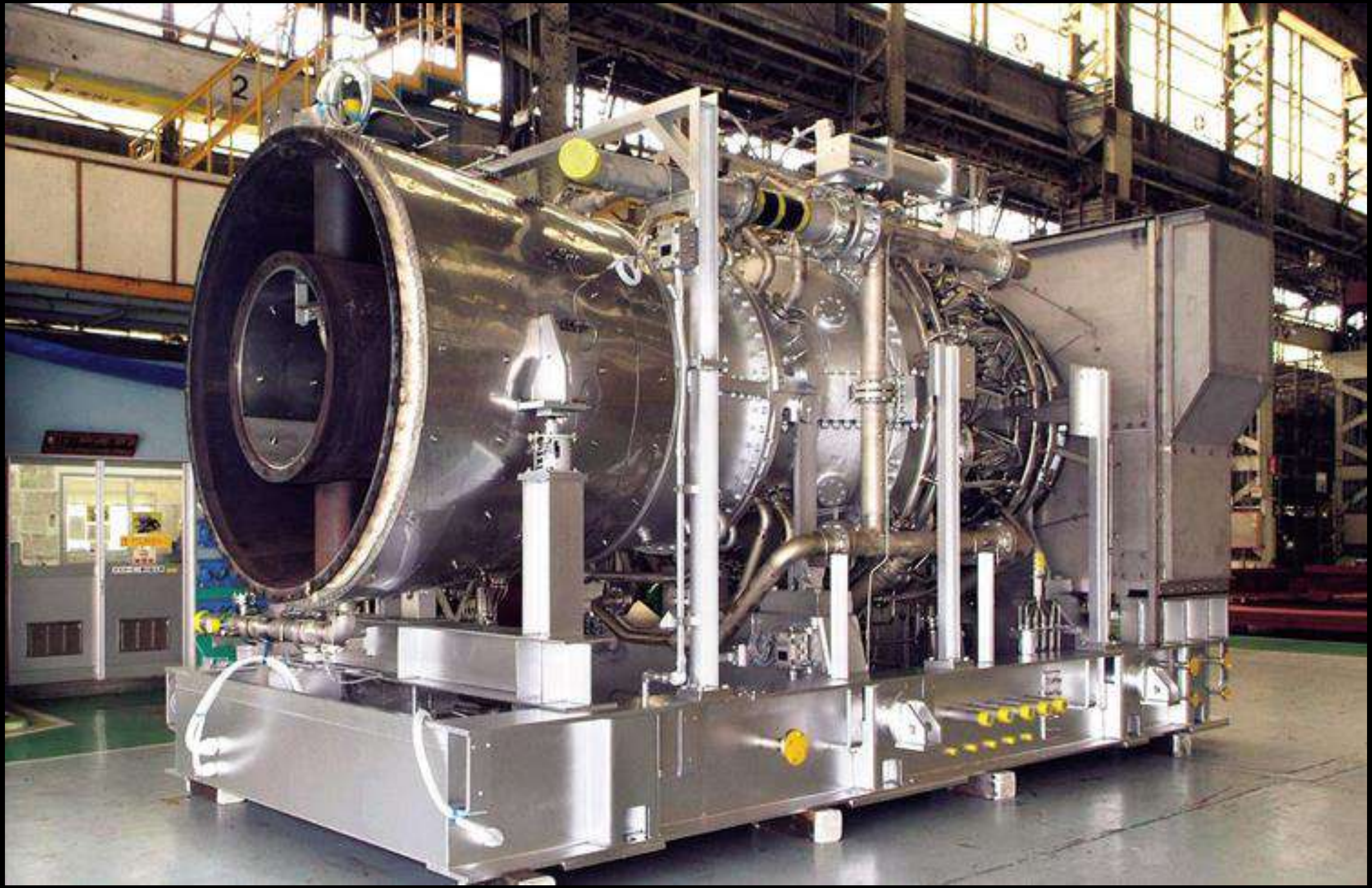
Initial calculations: 60%

(compared to ~80%)



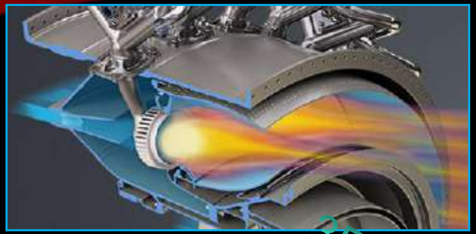
Different cycle strategies and LCA (that consider various scenarios) are under research to determine a conditions for high efficiencies a whole ammonia/hydrogen comparable to DLN technologies.

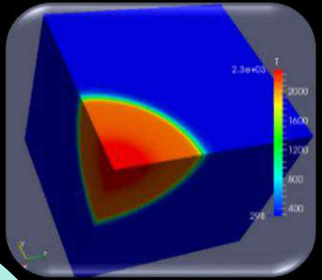
DEVELOPMENTS- AMMONIA GAS TURBINES

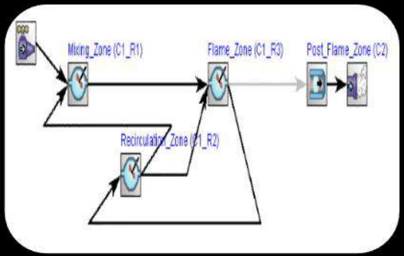


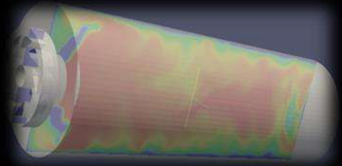
First Ammonia Gas Turbine Engine, MHI (H25), 40 MW Power
[https://power.mhi.com/news/20210301.html**]**

DEVELOPMENTS – AGT









We are here!

Spherical combustion

1D Simulation with current models

Initial flame experiments

2D Simulation and simple chemical modelling

Complex flames phase 1

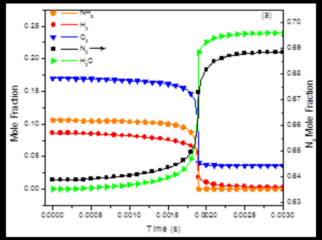
Complex flames phase 2

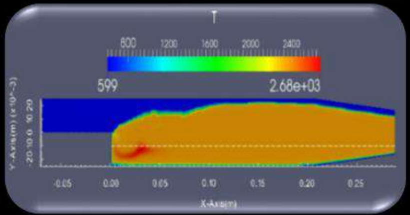
Development of small reaction mechanism

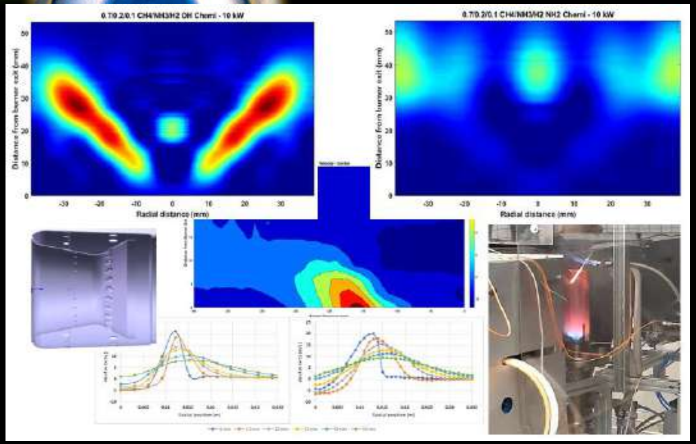
3D Simulation with accurate reaction model

Implementation in APU

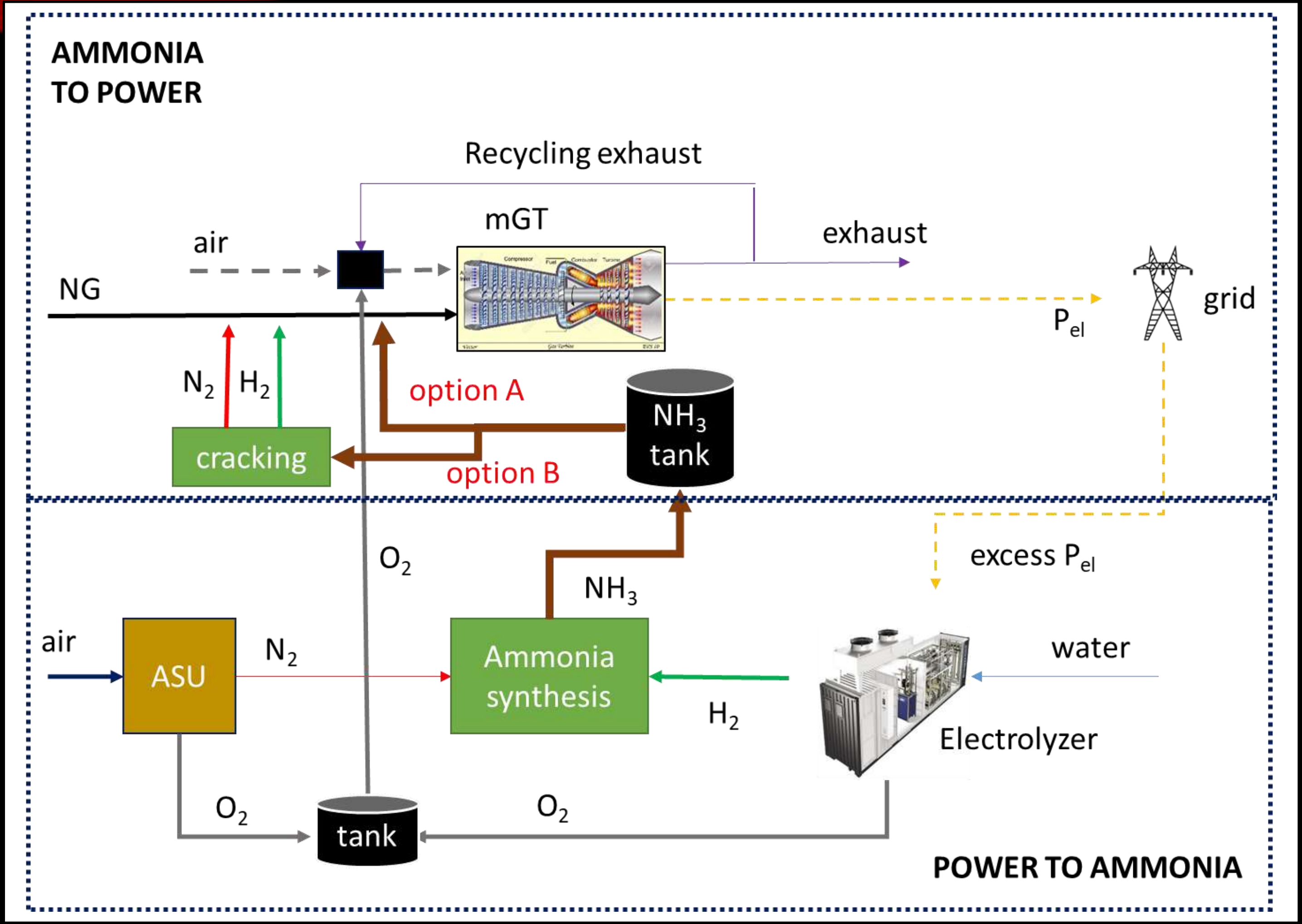
Demonstration of concept large scale

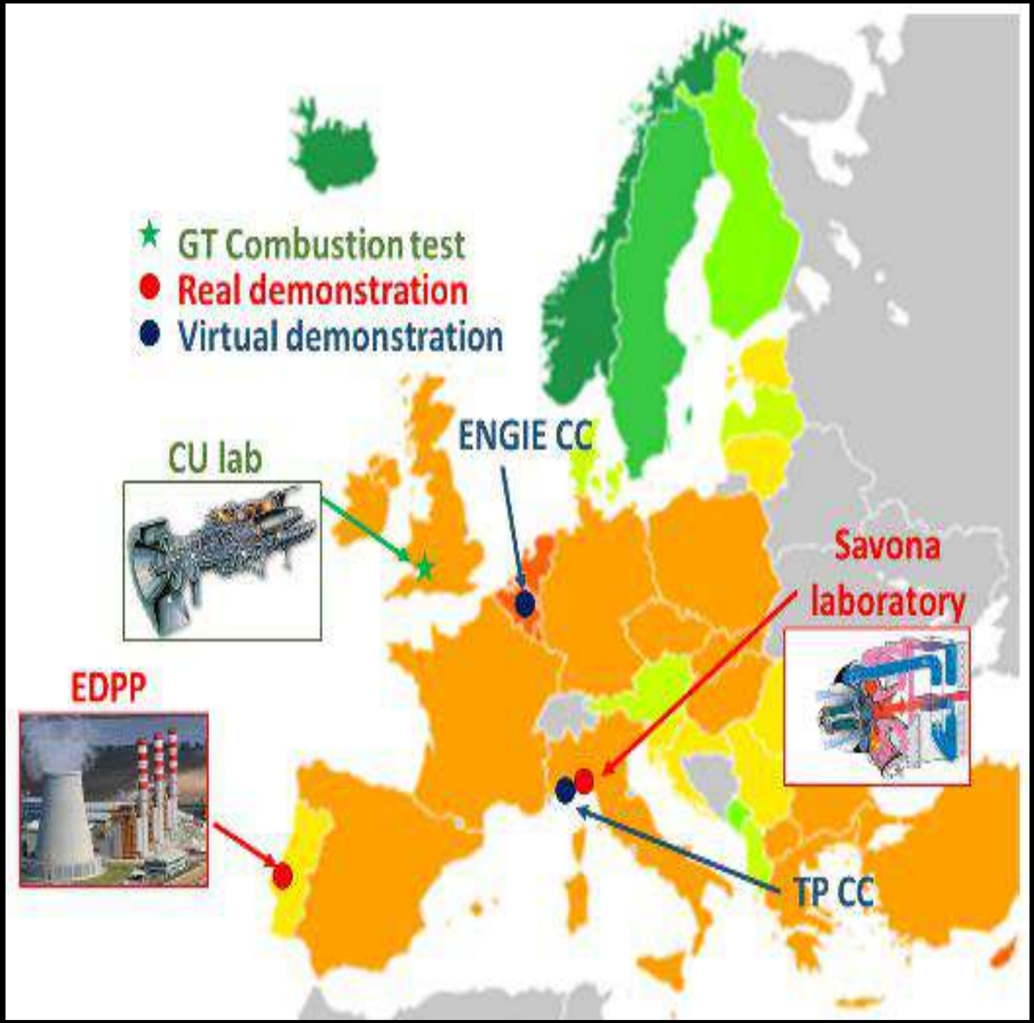






DEVELOPMENTS – AGT EUROPE





FLEXnCONFU – First large GT ammonia/hydrogen/NG demonstrator

COLLABORATION

NUS National University of Singapore
EPRI Electric Power Research Institute
University of Leicester
Imperial College London
Science & Technology Facilities Council
Shanghai Jiao Tong University
KAUST
Newcastle United
Tokyo Gas
Tata Steel
University of Twente The Netherlands
UCL
University of Oxford
Trinity College Dublin The University of Dublin
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European Turbine Network
Yara
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Sandia National Laboratories
University of Birmingham
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HiETA technologies
The University of Nottingham
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Lloyd's Register
mca Maritime and Coastguard Agency
AIST
深圳大学 Shenzhen University
東北大学 Tohoku University
Ricardo
Airbus
Massachusetts Institute of Technology
TU Delft
KIST Korea Institute of Science and Technology
NREL National Renewable Energy Laboratory
University of Strathclyde
Jiangsu University
bp
Universiti Teknologi Malaysia
Cairo University
ISSUGE Istituto di Studi Superiori dell'Università di Genova
Quantum ES Gas Engines

CONCLUSIONS

- Ammonia can be used to decarbonise cooling, heat, power and propulsion generation.
- Ammonia blends can be used efficiently, with low NOx, and production of species that can be used for combined processes.
- Research is on its way to implement new technologies in all spectra of technology for energy generation.
- However, for the "Hydrogen through Ammonia" economy to happen, lower costs and higher efficiencies of conversion from renewables are needed.
- Support needs to be provided to all different fronts to achieve the profitable implementation of a "Hydrogen through Ammonia" Economy worldwide.

THANKS FOR YOUR ATTENTION

FURTHER INFORMATION: VALERAMEDINAA1@CARDIFF.AC.UK

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