A Feasible alternative to Natural Gas for Achieving Net-Zero Targets in Space Heating

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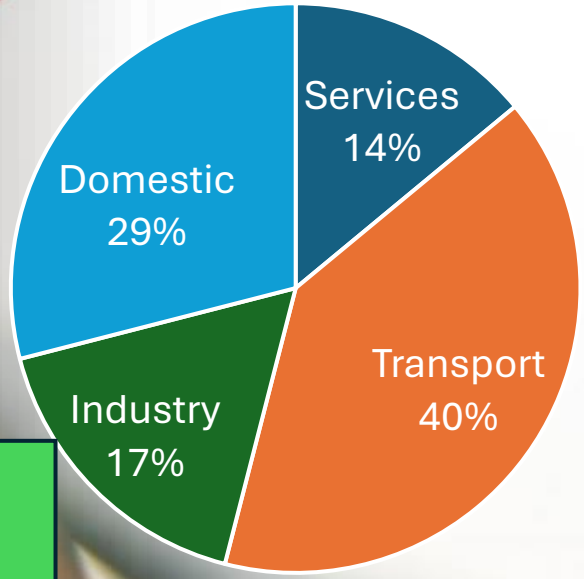
Net-zero carbon emission

Residential heating sector is responsible for about **30% of the UK's CO2 emissions**

that

remains **heavily dependent on natural gas**.



- By **2030**, the UK aims to reduce greenhouse gas emissions by 68% compared to 1990 levels.
- By **2050**, the UK aims to achieve net-zero carbon emissions
- From **2025**, new homes in the UK will **not be permitted** to install gas boilers

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Available alternatives to natural gas

Heat Pumps

Strain the electricity grid; Require costly infrastructure upgrade

Electric heating

Strain the electricity grid; Require costly infrastructure upgrade

Hydrogen

significant storage and safety concerns; Unsuitable for residential applications

Biogas

Corrosive; Inconsistent energy content; Storage challenges; Odour issues; Upfront costs

Ammonia

Corrosive; Toxic; odour issue;

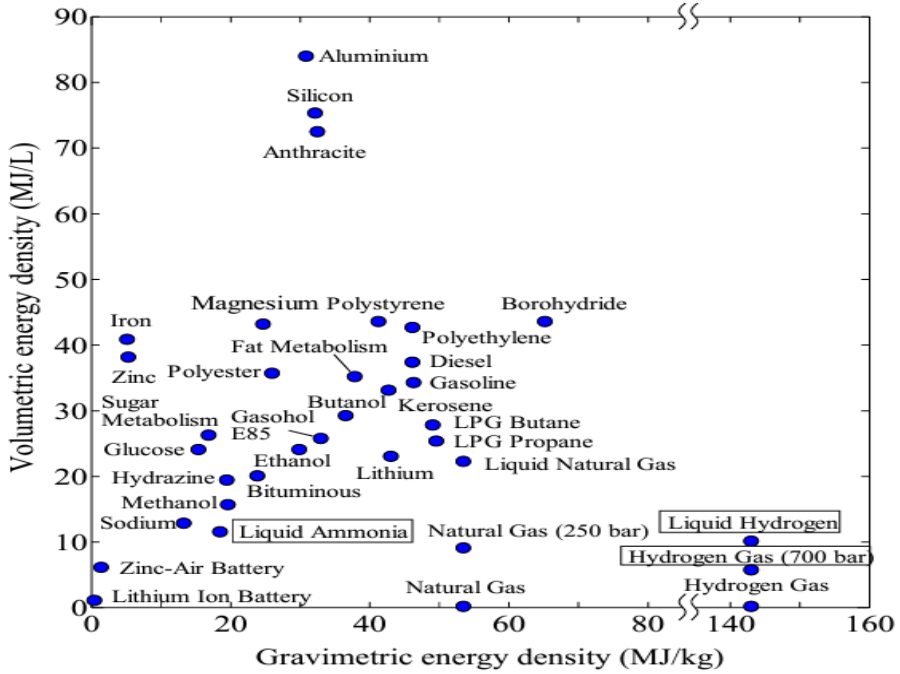
Hydrogen; Challenges

- Hydrogen **has one third of energy density by volume** compared to **natural gas**, which can lead to increased energy loss during storage and transportation.
- **Adapting** existing natural gas pipelines for hydrogen could cost approximately **£3 billion to £5 billion** in the UK alone.
- It is estimated that **over 85%** of the existing gas distribution network may require modifications or replacement to accommodate hydrogen.
- **Explosive Potential**: Hydrogen has a **higher energy release upon ignition**, with about **120 MJ/kg** compared to natural gas at **50 MJ/kg**.

There is still a long way to go before hydrogen can be widely implemented for residential heating, making it unlikely to be feasible by 2050.

Ammonia

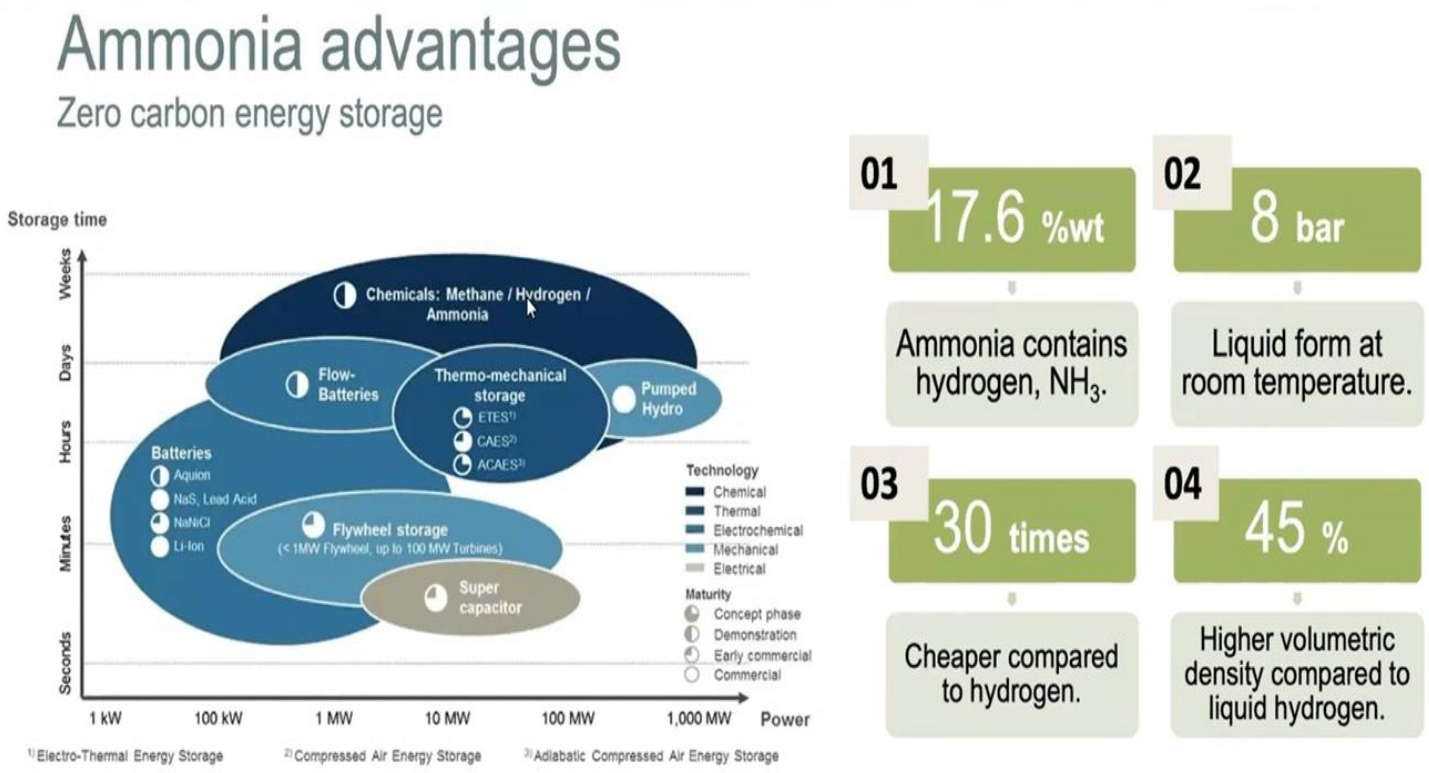
- **High energy density**: Ammonia offers a volumetric energy density approximately **350 times greater** than that of **natural gas** at standard conditions.
- At moderate pressure, ammonia remains in **liquid phase** at **ambient temperature**, making it manageable.
- Pungent odour facilitates leakage detection.



Ammonia

- Easy to **store and transport** compared to hydrogen.
- The density of **ammonia** at just **12 bar** is **600 kg/m^3**, whereas **hydrogen** at **700 bar** hardly reaches **40 kg/m^3**. (Ambient temperature).
- **Ample Hydrogen Carrier**.

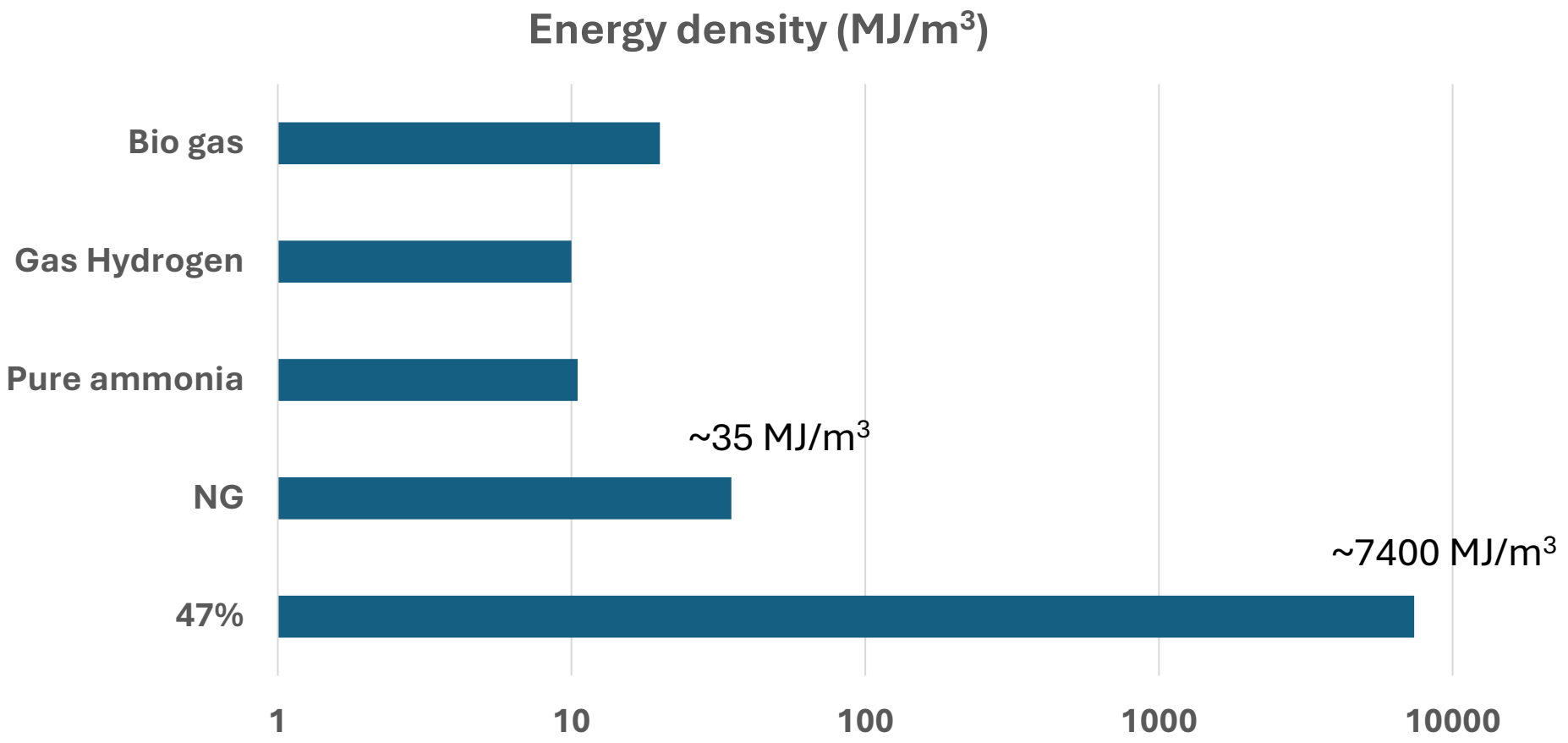
Toxic
Corrosive



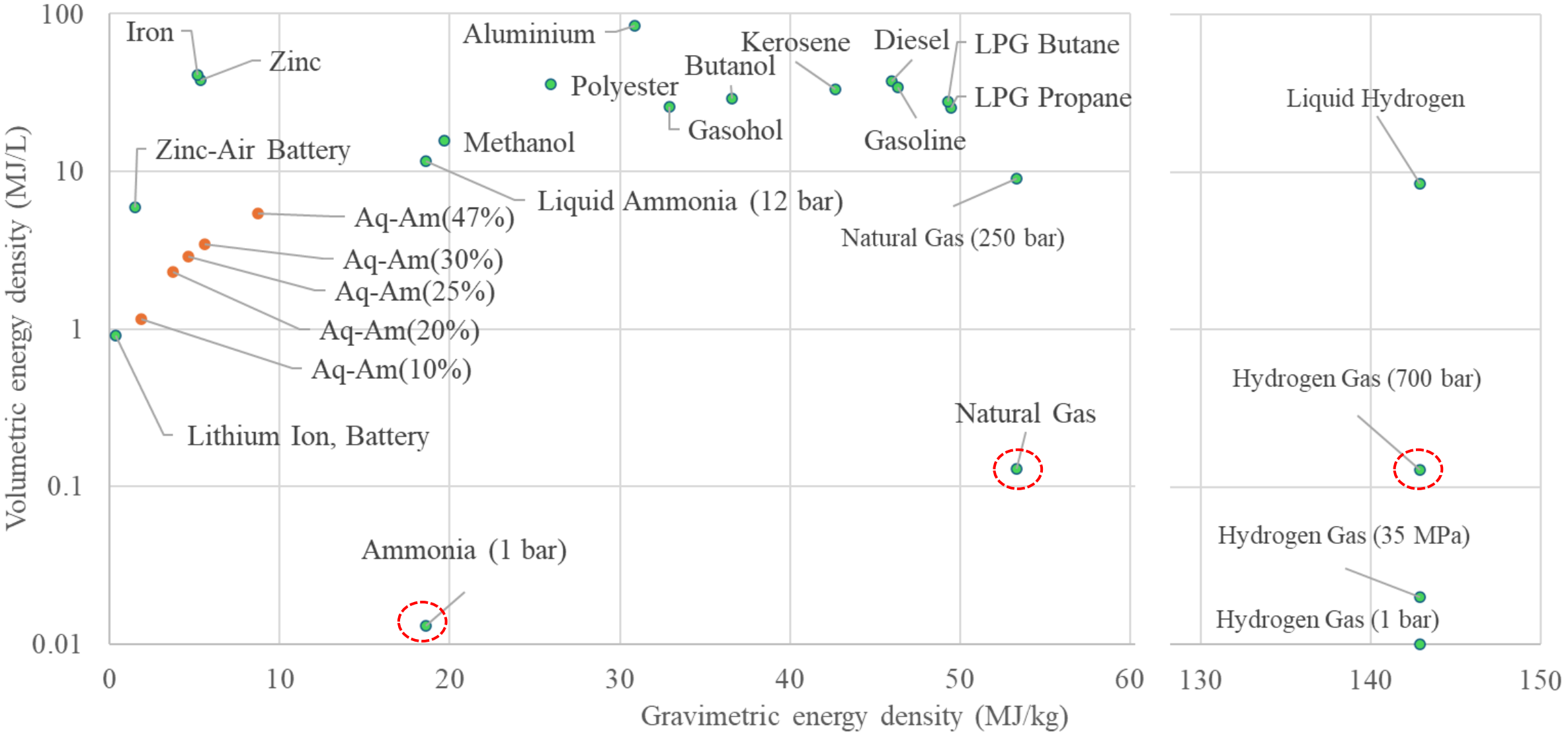
Aqua Ammonia

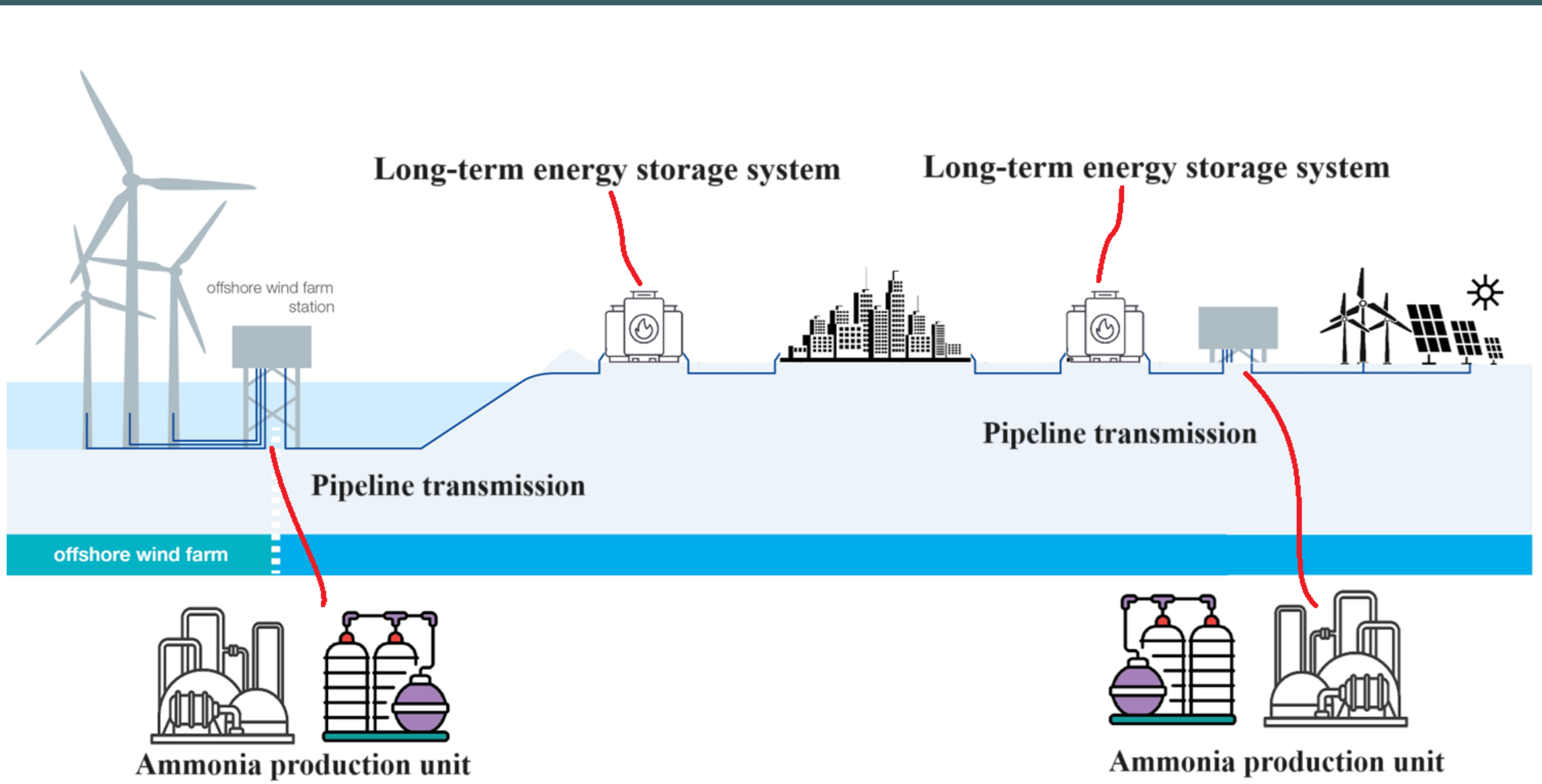
- Formed by dissolving gaseous ammonia in water; Water can absorb an amount of ammonia equal to its own weight.
- **Shares the benefits** of pure ammonia—carbon-free, high-energy density, and renewable production—while **minimizing its drawbacks;**
- **Less Toxic;**
- **Less corrosive;**
- **Liquid at ambient conditions**;
- **Higher volumetric Energy density than NG, Pure ammonia, hydrogen**
- Transportable with **current NG pipeline,** With **8 times more energy than NG**
- Easy to Store;
- Cost-effective to transport;
- **Ample Hydrogen carrier**

Ammonia


Energy density (MJ/m3)
Bio gas
Gas Hydrogen
Pure ammonia
NG
47%
~35 MJ/m3
~7400 MJ/m3
1
10
100
1000
10000

Ammonia


Volumetric energy density (MJ/L)
100
10
1
0.1
0.01
Iron
Zinc
Aluminium
Kerosene
Diesel
LPG Butane
Butanol
Polyester
LPG Propane
Gasohol
Gasoline
Zinc-Air Battery
Methanol
Liquid Ammonia (12 bar)
Aq-Am(47%)
Natural Gas (250 bar)
Aq-Am(30%)
Aq-Am(25%)
Aq-Am(20%)
Aq-Am(10%)
Lithium Ion, Battery
Natural Gas
Ammonia (1 bar)
0
10
20
30
40
50
60
Gravimetric energy density (MJ/kg)
Liquid Hydrogen
Hydrogen Gas (700 bar)
Hydrogen Gas (35 MPa)
Hydrogen Gas (1 bar)
130
140
150


Long-term energy storage system
Long-term energy storage system
offshore wind farm station
Pipeline transmission
Pipeline transmission
offshore wind farm
Ammonia production unit
Ammonia production unit

Carbon-Free Energy Delivery Through Low-Pressure Pipework Using Aqua-Ammonia

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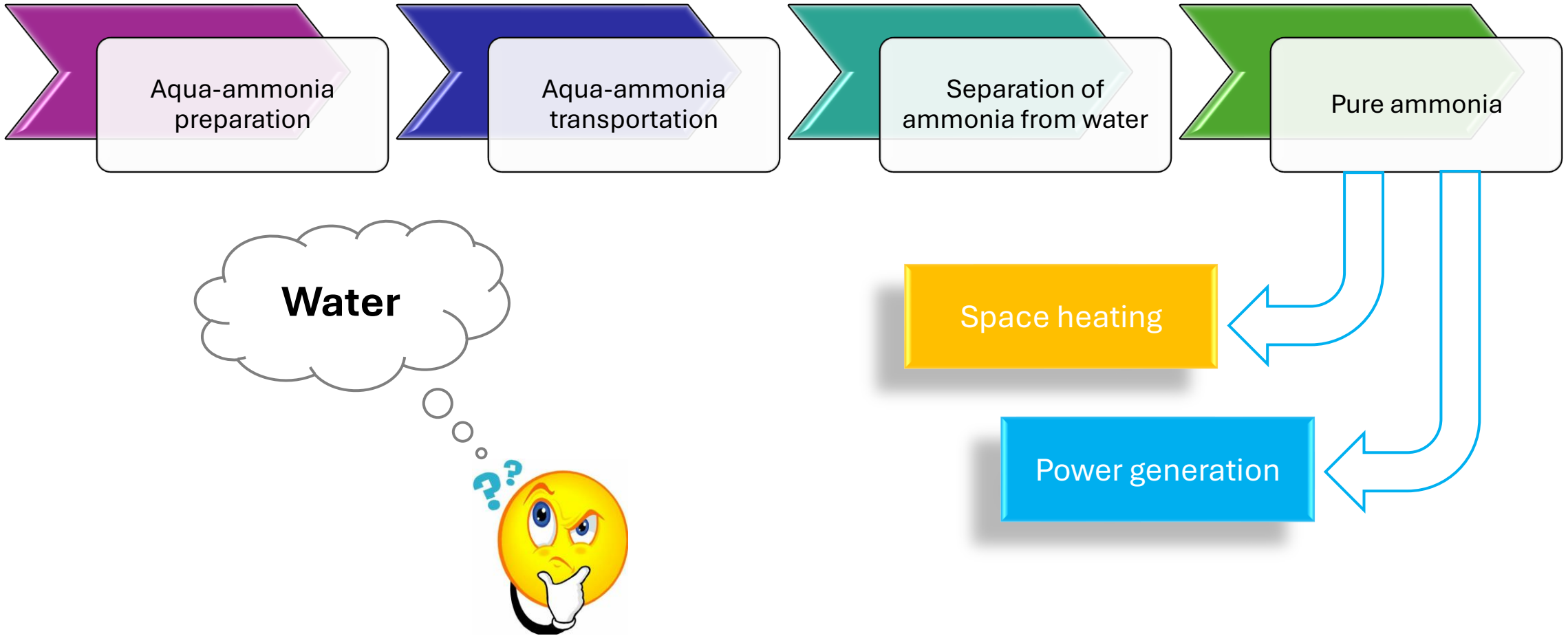
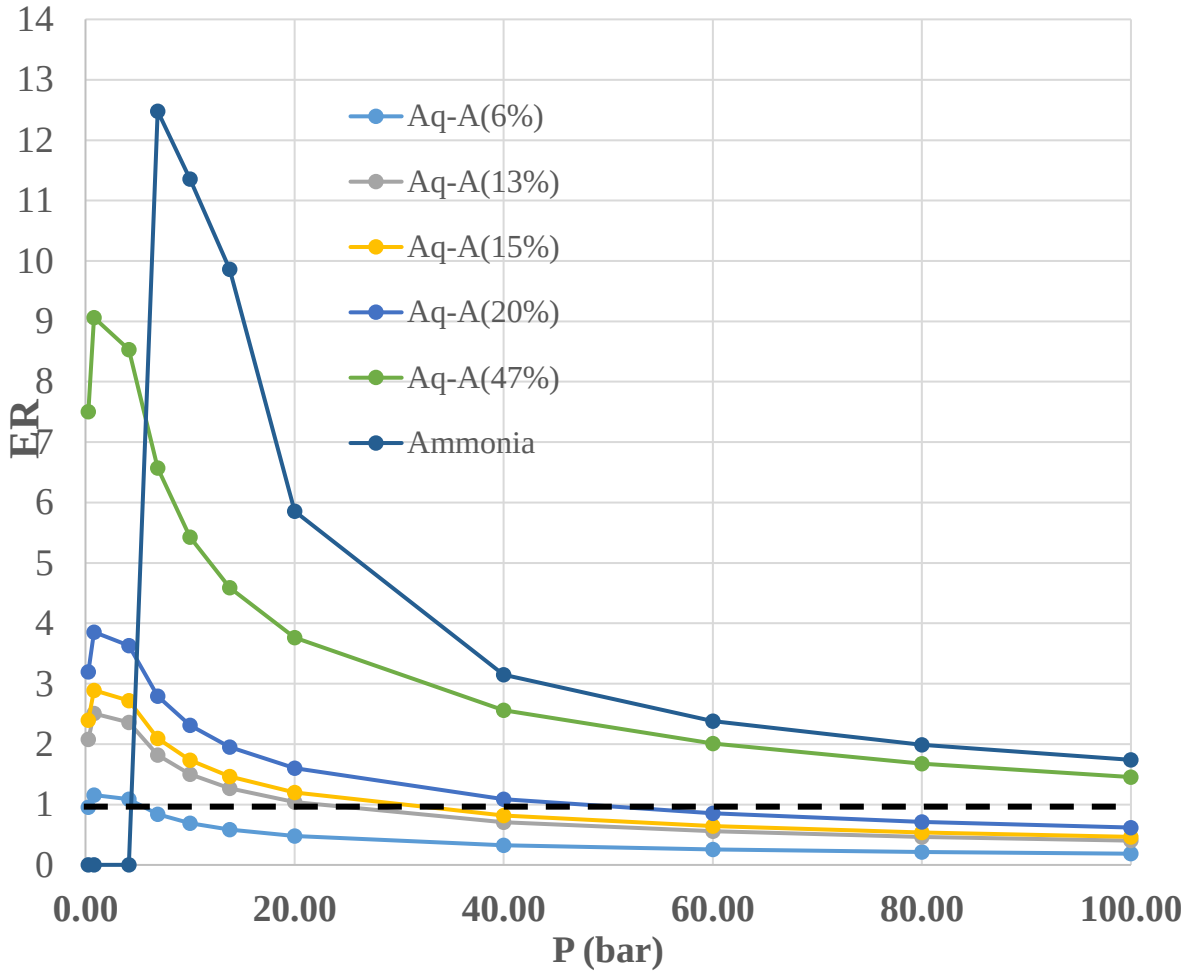
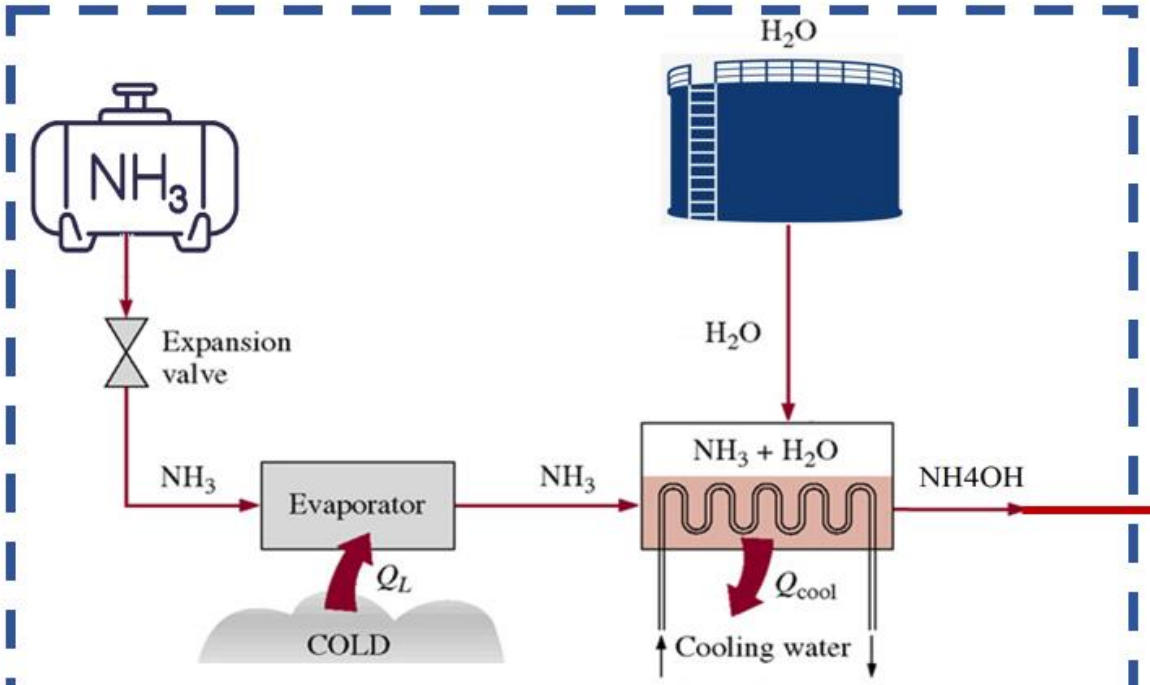


Compatibility with current infrastructure

- Material Perspective
- Operating condition (pressure, Temperature)
- Capacity

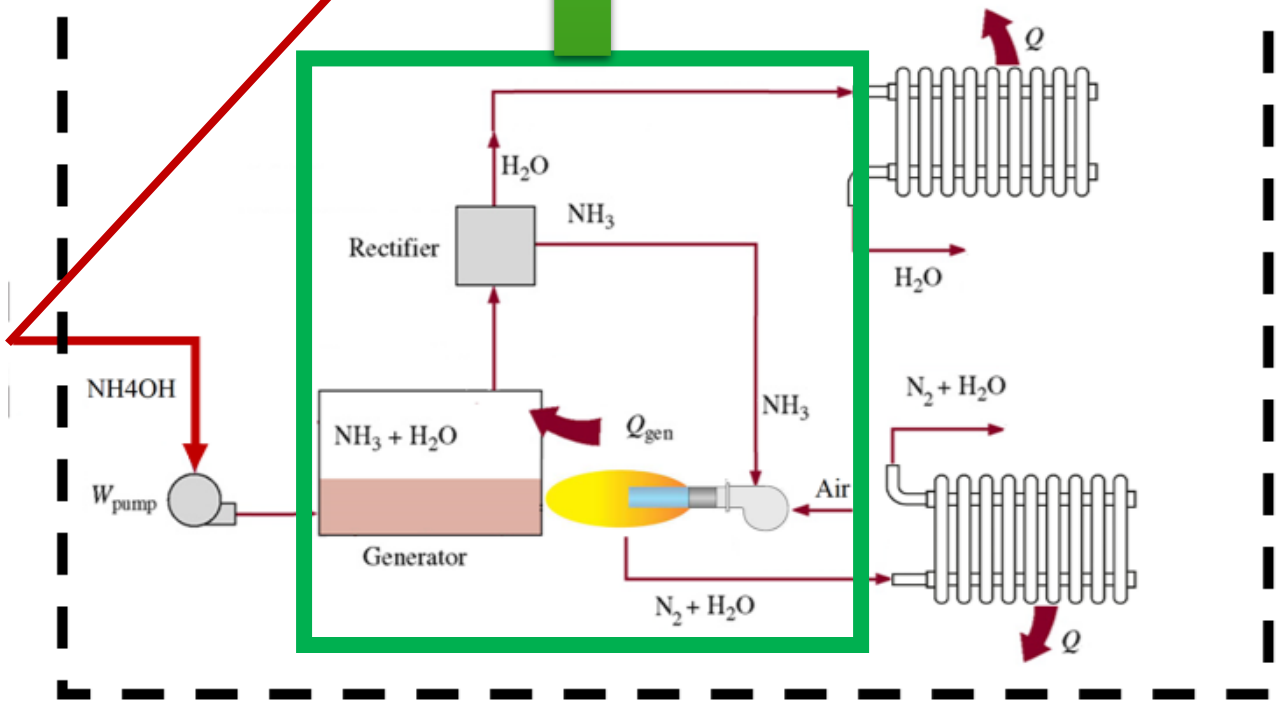


Intercity pipelines: ~70 bar
Within city urban areas:~ 0.7-14 bar



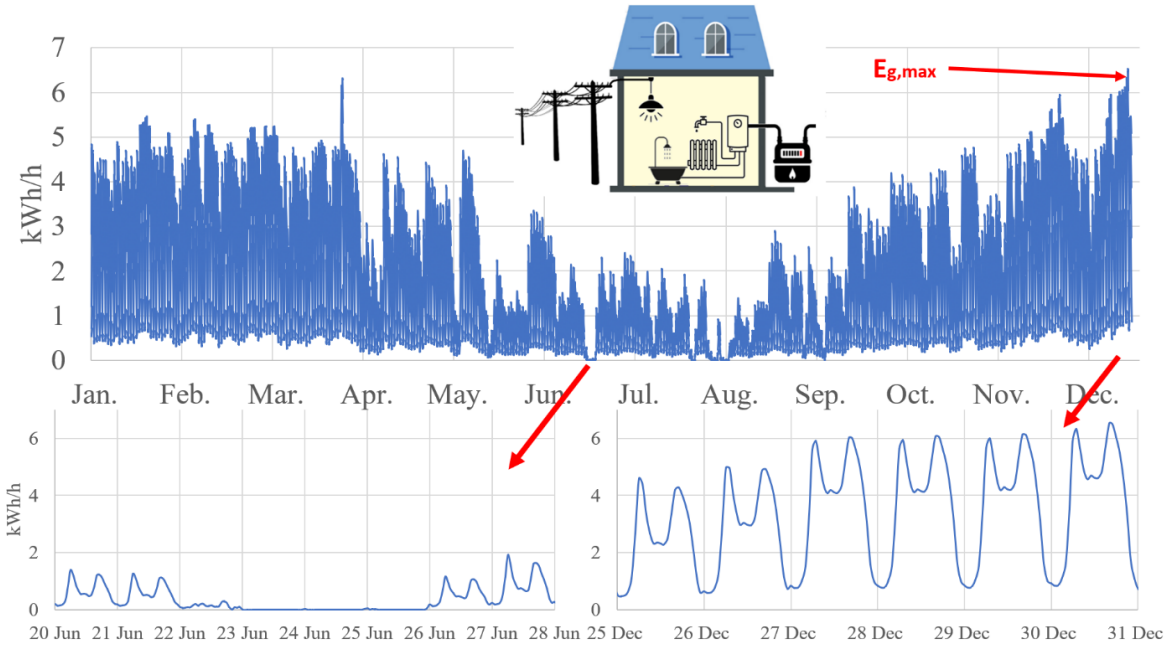
“Aqua-Ammonia Boiler”

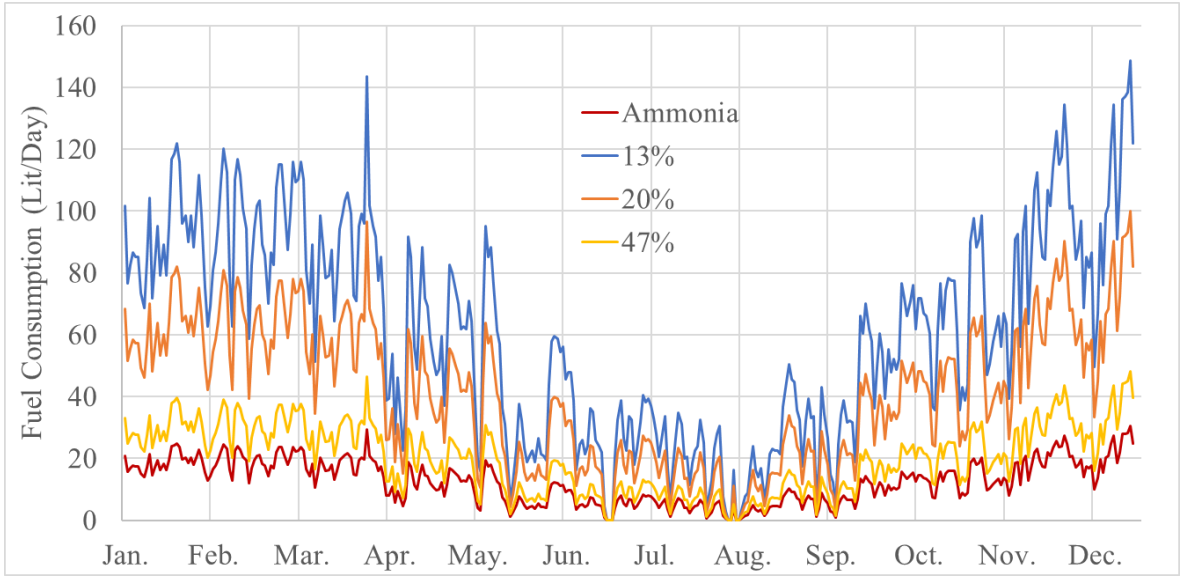
- Separation unit
- Ammonia burner
- Heating system



Aqua-Ammonia for Residential Heating

Thermal Performance of the Aqua-Ammonia boiler





Energy Storage Potential of Aqua-Ammonia

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In 2022, Great Britain consumed around **450 TWh of gas**—equivalent to burning approximately **90 million tons of ammonia**.

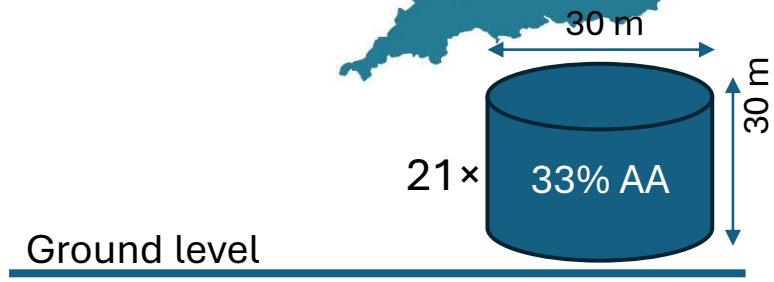
To store the whole fuel for one year

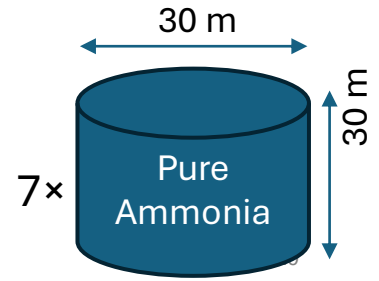
21 Aboveground Tanks of 33% Aqua Ammonia

Atmospheric pressure
Liquid
Above ground
Safer

7 Underground Tanks of Liquid Pure Ammonia

At 12 bar pressure
Deep underground
Liquid; vulnerable to dangerous phase change





Advantages of the proposed idea

- Aqua-Ammonia is an alternative to NG with 50-200 times greater energy density at 10-40% concentration.
- Liquid at ambient conditions.
- Safer fuel in terms of explosion risk in comparison with Hydrogen and even NG.
- High-energy transport in a compact volume.
- The system has the **capability to generate electricity, thermal, and even cooling energy**.
- In terms of **positioning**, **the fuel transportation concept performs better than natural gas**.
- Simultaneous transfer **of energy and water**
- Suitable for use **in water-rich and water-scarce countries**.

Conclusion

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- **The involving subsystem technology is already established; Practical to meet the 2050 target** with the **least possible adjustment because aqua-Ammonia is compatible with current NG infrastructure.**
- It can be simply adopted for **residential heating; Just the Aqua-Ammonia Boiler will replace the conventional gas boilers.**
- **With current capacity of NG pipeline 8 times more energy can be transmitted by Aqua-Ammonia.**
- This is an alternative fuel that can replace NG in any application which is currently dependent on NG.
- Carbon-free energy delivery system from renewable resources to demand sites.

From **a social perspective**, while **hydrogen is known for its explosion hazards**, ammonia has different history. Pure ammonia **was commonly used in residential refrigerators until the 1950s. In cleaners, ammonia concentrations typically range from 5%-25%.**

TRL (Technology Readiness Level)

- The project has **completed** **idea generation, simulations, designs, Prototype fabrication and tests for separating ammonia from aqua-ammonia**, achieving promising results.
- Based on the novel separation method that **was funded by UKRI**, we achieved **17 ppm ammonia left in water** that is a great success. **Separation unit** is ready for scaling and practical implementation.
- The whole **Aqua-Ammonia Heating Boiler** is **designed and in the process of prototype fabrication**.
- Compatibility with current infrastructure is investigated.

Stakeholders

- Anyone interested in developing scalable, low-carbon solutions to combat climate change!
- **Gas Network operators**
- All **Boiler manufacturers**; Future-proof solution against regulations!
- All **power plants** currently dependent on Natural Gas!
- All industries and researchers who are involved with **Hydrogen**; The best Hydrogen carrier.
- **Energy Utility** Companies
- **Green Power plants**

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Thank you !

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Economic Perspective