



MINISTRY OF NEW
AND RENEWABLE ENERGY
GOVERNMENT OF INDIA



MINISTRY OF PETROLEUM
AND NATURAL GAS
GOVERNMENT OF INDIA

OFFICE OF THE PRINCIPAL
SCIENTIFIC ADVISER TO THE
GOVERNMENT OF INDIA



INTERNATIONAL CONFERENCE ON GREEN HYDROGEN 2023

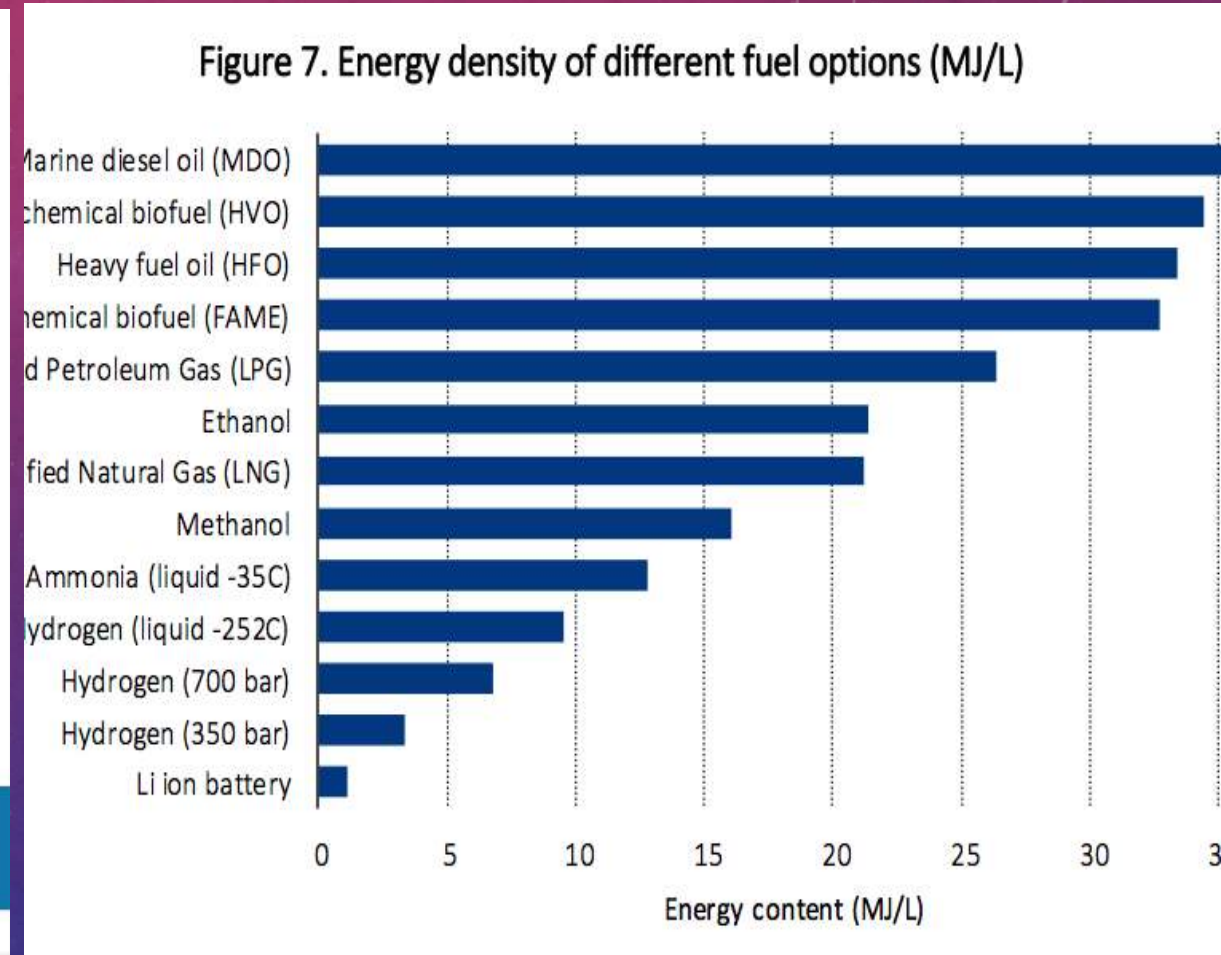
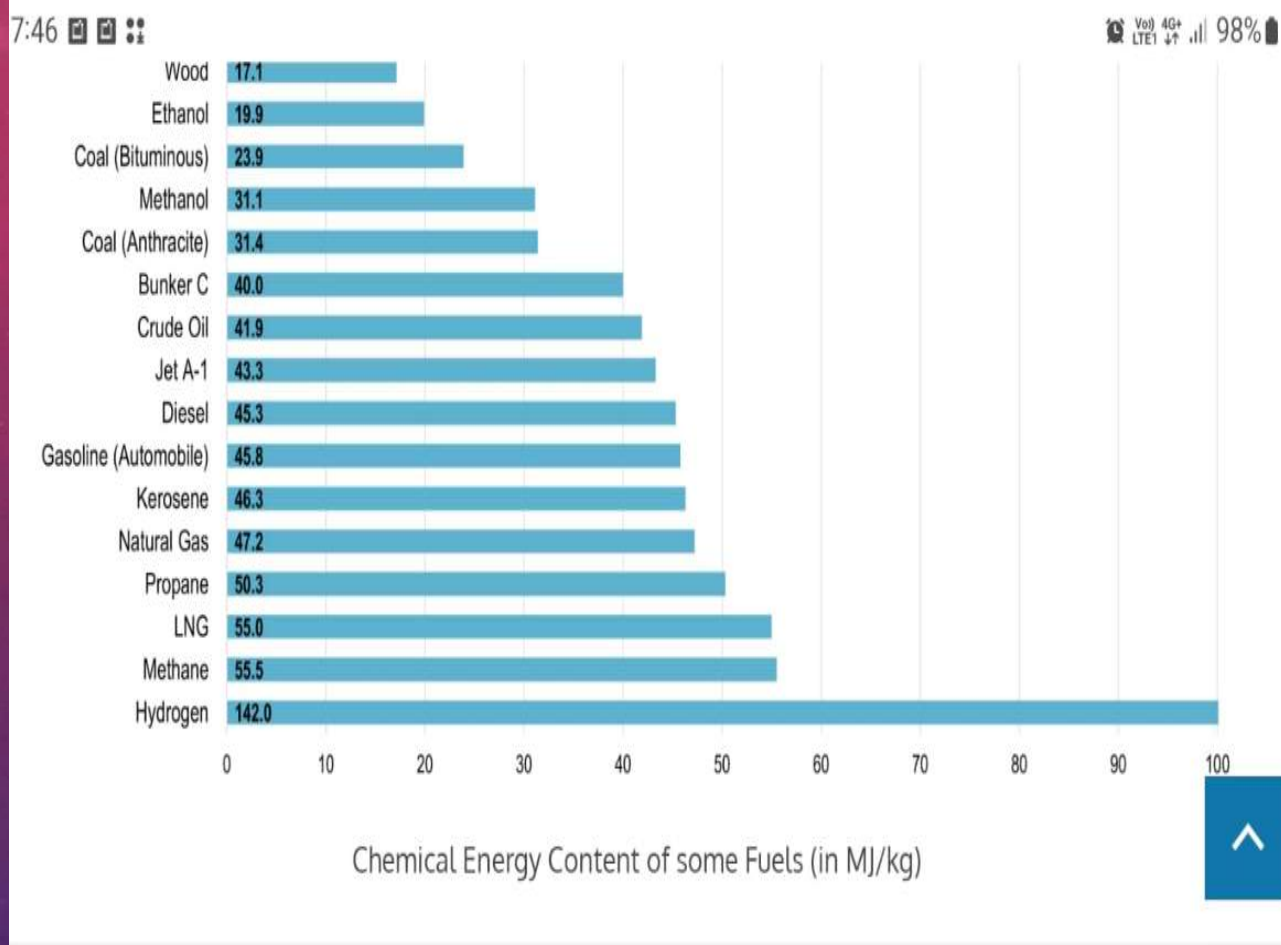
HYDROGEN STORAGE, DISTRIBUTION AND REFUELLING

A HISTORICAL BACKGROUND

- Hydrogen is a unique gas with one of the longest history since the gas is key in various process industries
- 17th century – various Hydrogen related scientific activities
- 18th century – first hydrogen electrolyzers & hydrogen balloon
- 19th century – first fuel cell and the famous Hydrogen Zeppelin
- 1966 – first Hydrogen automobile
- In short, Hydrogen has been a key element since centuries



HYDROGEN IS AN OPPORTUNITY & CHALLENGE

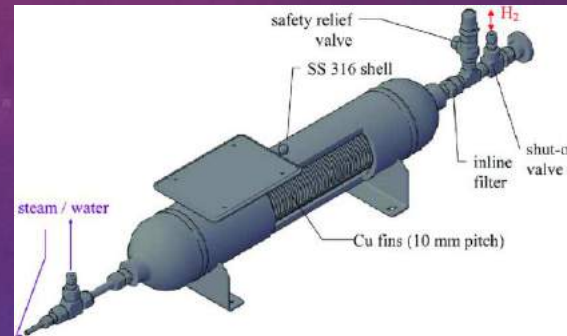


Hydrogen has the highest energy content but the lowest storage density

This is what presents the biggest challenge in Hydrogen applications

STORAGE & DISTRIBUTION OPTIONS

- Salt Caverns
- Cryogenic storage – proven technology
- High pressure composite tanks – proven technology
- Cryo-compressed storage – demonstrated, under commercial development
- Metal Hydride storage – A story being heard since long
- Pipelines – will take time but existing infra can be a solution with rigorous technical due diligence



STORAGE AND DISTRIBUTION IS THE WEAKEST LINK

- Storage/ Transport is the KEY for the success of the hydrogen economy in India.
- Global companies not demonstrating manufacturing commitment due to huge business in Europe/USA
- Composite cylinders are the preferred solution for both storage and transportation globally
- Type 3 or Type 4 composite tanks are technically well proven upto 350 bar, Type 4 tanks become preferred option above this.
- Any tank option uses Carbon fiber and this drives cost up significantly
- Today a 250 bar system could be more cost effective than a 500 bar system as storage at 500 bar is only 1.75 times than at 250 bar but is 2.5x+ in cost.
- Trucks today theoretically store about 30 kgs of Hydrogen at 350 bar, giving a range of about 250 kms
- Just 5,000 trucks across India will mean 150,000 Kgs of Hydrogen per day per fill

**Even High-pressure composite tanks are a challenge – for say
10,000 kgs of H₂**

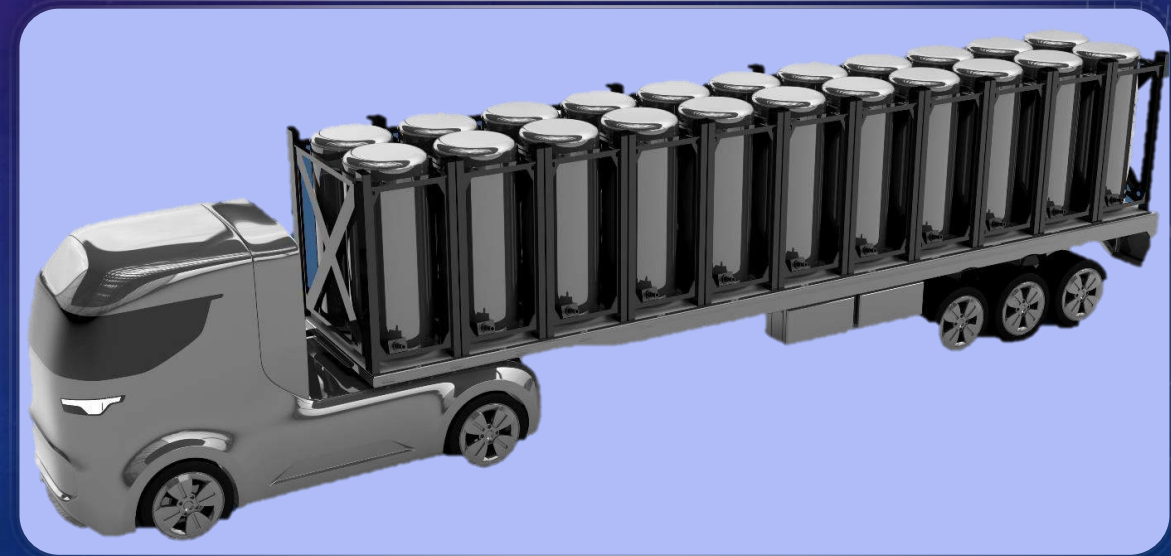
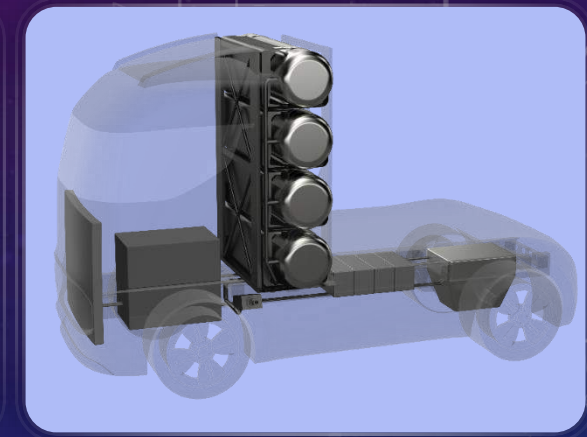
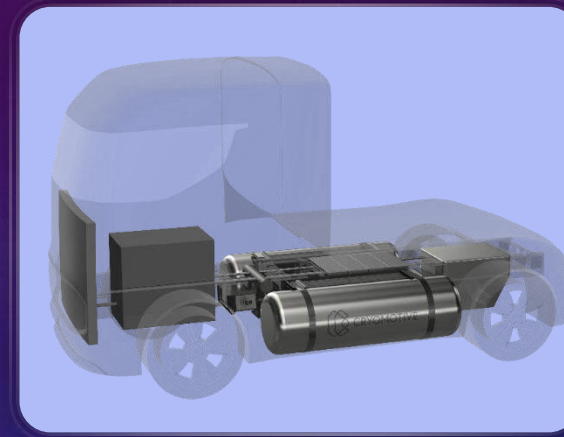
Pressure	WC	H2 Kgs	No. of tanks	Pr Ratio	Fill Efficiency
250 bar	1,666	30.9	324	1.00	1.000
250 bar	8,500	153	65	1.00	1.000
300 bar	1,666	35.9	279	1.20	1.194
350 bar	350	8.4	1,190	1.40	1.333
450 bar	1,666	48.7	205	1.80	1.622
500 bar	330	10.5	952	2.00	1.767

CHALLENGES IN THE SUPPLY CHAIN - TODAY

- Understanding end use & designing ground storage/transport solutions for lowest cost
- Mumbai to Delhi is 1500 kms or 6 refilling's of 30 kgs per truck
- 5,000 trucks will mean 7,50,000 Kgs of Hydrogen per trip.
- This is about 16,000 ~ 20,000 Large tanks for transporting gas per day Or 5 to 10 Tank manufacturing lines given today's global data
- Given the projected numbers on Hydrogen in India – local manufacturing is an absolute must
- Backward integration into carbon fiber manufacturing will be key for commercial success – 75% of tank cost
- Today a combination of import costs & other costs make the solutions unviable commercially
- Storage cost needs to factor in cost of compression since system cost is key and significantly affects supply chain costs.
- Even with local manufacture costs can be higher than Europe unless system costs can be reduced by regulation
- Every cylinder must have a valve which drives transportation module costs up – globally manifolds used & parts reduced
- We have BOTH pressure and temperature safety – increasing cost. Globally they focus on temperature (fire) safety
- Gas transport modules cylinders cannot be more than 600 mm diameter making designs inefficient, costly.
- Composite cylinders periodic retesting treated same as steel making effort costly, reduces safety.

CRYO-COMPRESSED GAS – THE FUTURE?

- Efforts are underway to develop a hybrid technology wherein cryogenic temperatures with high pressure composite tanks combine to give greater storage efficiency
- Technology under advanced stage of development – expected to be ready by 2024/2025 – already demonstrated in the field
- Cryo cooled gas at upto 400 bar pressure in composite cylinders qualified for cryogenic temperatures
- Trucks can have around 100 kgs of H₂ storage and bulk transport upto 2,500 kgs of Hydrogen
- Tech offers 40% volumetrically denser than 700 bar on a system level
- Station costs are said to be 25% of a 700 bar CGH₂ gas station as Total Cost of Ownership
- While various storage technologies offer promise, this currently looks like a game changer



INDIA HYDROGEN WISHLIST

- **Technology and the Hydrogen industry itself is evolving globally and so India needs to be flexible to quickly factor in changes**
- **Flexibility to deviate from existing norms across CMVR, RTO, PESO to demo overall technology & design validation**
- **While Green is good – suggest interim step of establishing a Hydrogen eco-system as priority**
- **Import duty waiver on import of tanks for global tank suppliers who commit on a local tank manufacturing facility within 24 months**
- **Encourage Indian manufacturers to invest/ develop solutions for both tanks and CF, policy/ executive support to get access to raw material/ technical resources**
- **Direct and aggressive efforts by the Govt of India to bring both Tank and CF manufacturing into India – need to start now for plants to be ready in 36 to 48 months.**
- **In the short term – to reduce overall cost, plan self contained facilities on highways where Hydrogen is generated, compressed and delivered to trucks.**
- **Focus on applications where generation/ application of Hydrogen is at the same location to reduce compression/ storage costs**
- **Bulk transport of Hydrogen at 500 bar, Mobility applications at 700 bar and Ground storage at 950 bar must be allowed and encourage demonstration of various technology in the interim – like use of Jumbo composite tanks**
- **The first periodic recertification must be done by tank supplier only as a statutory requirement**



THANK YOU!

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