7/12/2022

NETSCo & ABB – Maritime Ammonia Synergies Using Inland Waterways

Ed Schwarz, VP Marine Systems

ABB

Global Megatrends Driving Marine Electrification

Exponential changes are expected

Digitalization

Urbanization

Carbon Free Resources

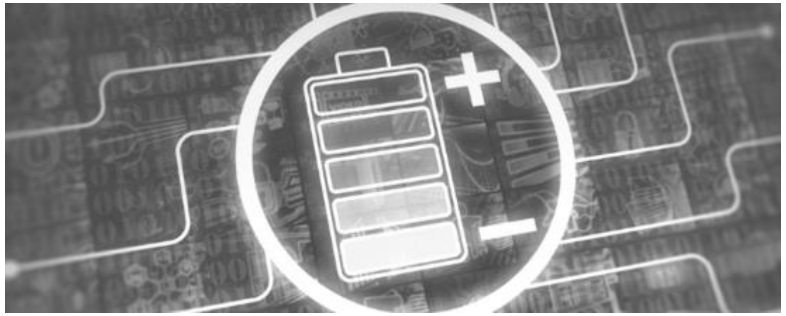
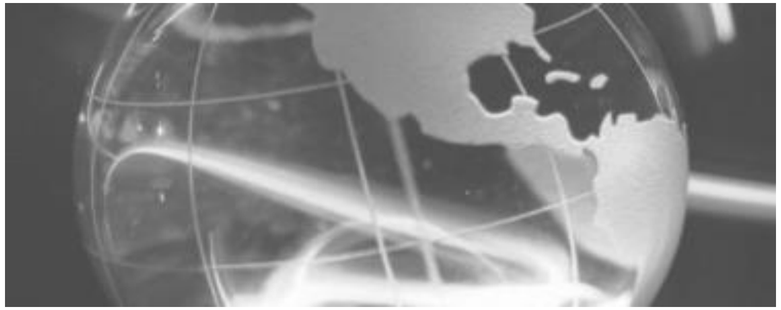


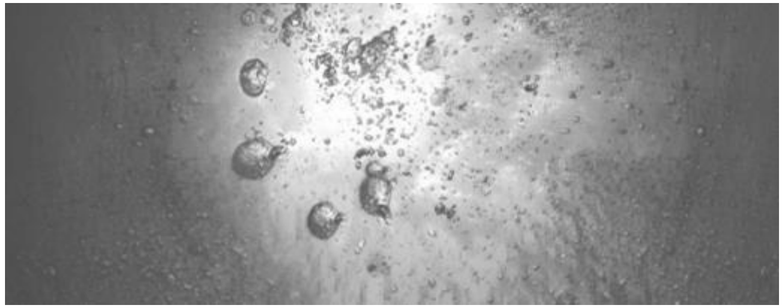
ABB and Chevron Shipping - April 27th & 28th 2022 - San Ramon, CA USA

Automation and Robotics

Global Economic Shift



Environment



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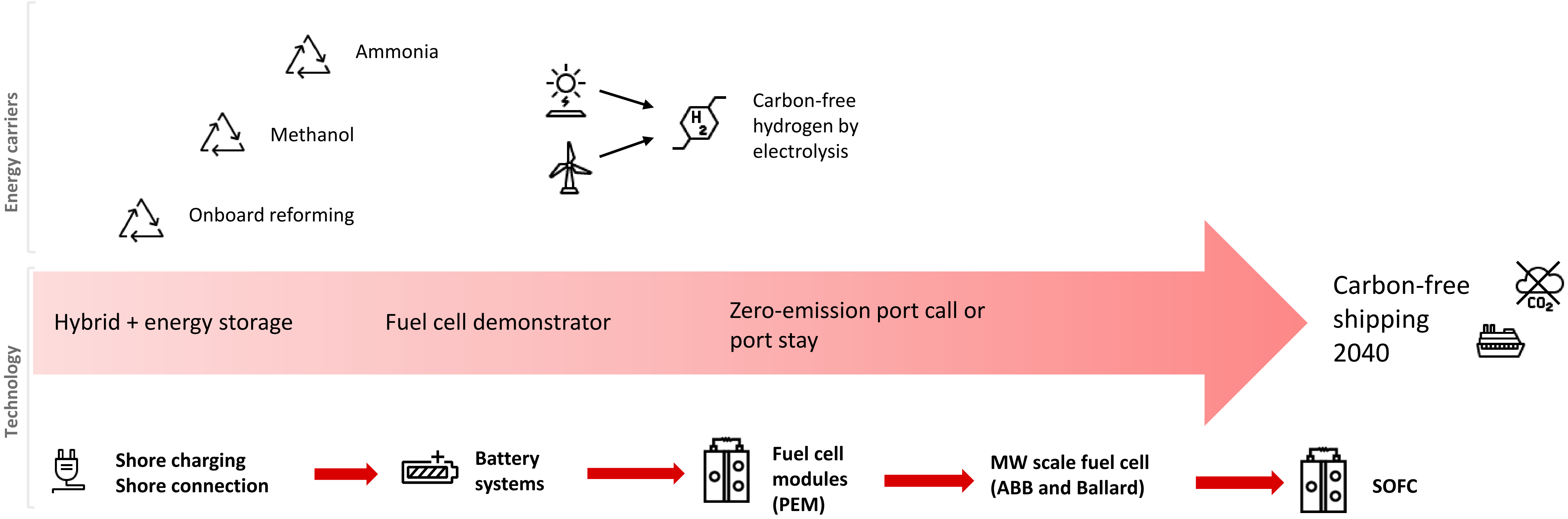
Pathway to carbon-free shipping

Transitions in **fuel** and **technology**

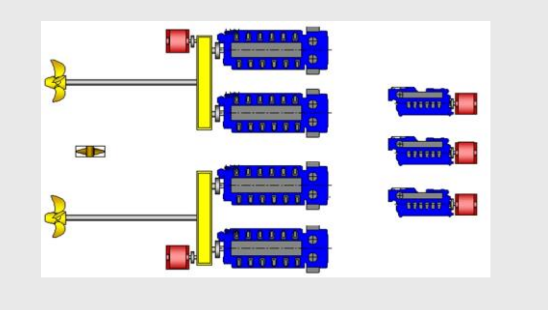


Evolution of Ship Propulsion

Pathway to carbon-free marine vessels

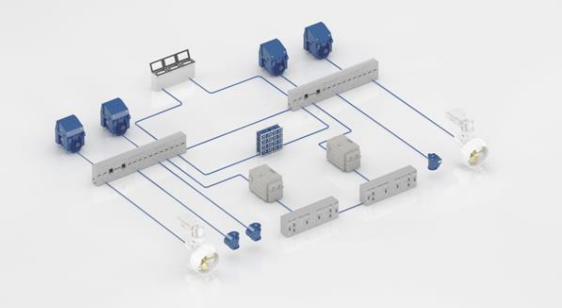
Mechanical propulsion

- Diesel engines, gearboxes and controllable pitch propellers for propulsion
- Separate auxiliary engines for electricity generation for ship use



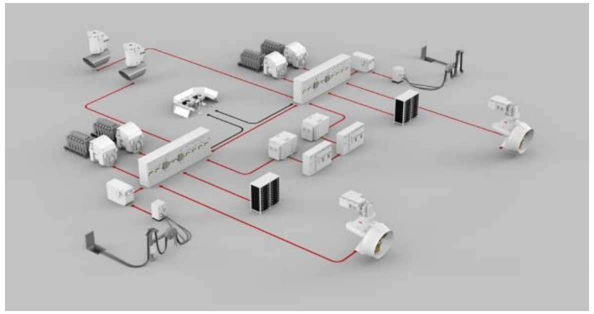
Diesel electric system

- Diesel-Generator sets to produce electricity to common grid for propulsion and ship use
- AC or DC Power Systems



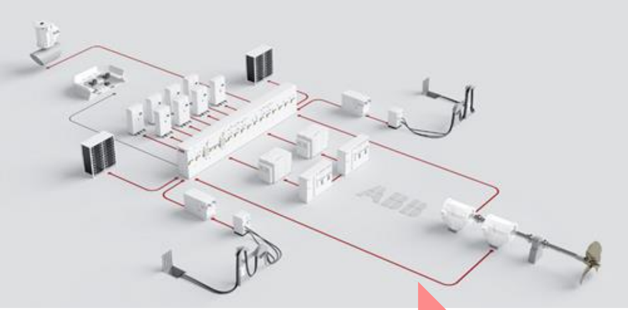
Hybrid electric system

- Diesel Generator sets to produce electricity to common grid for propulsion and ship use
- Batteries or/and Fuel cells to reduce emission or provide zero emission to <u>parts of the operation</u>



Fuel cell / battery electric

- Batteries or/and Fuel cells to provide all energy to enable zero emission for <u>all operations</u>
- Simple and complex charging systems- all power comes from shore power or alterative fuels



Historical → Proven but Not Optimal → Modern Standard (Commercially Mature) → Early Adopters (New Technology)

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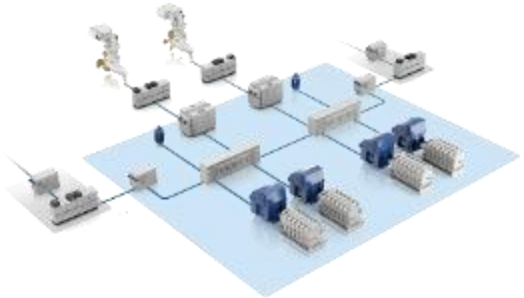
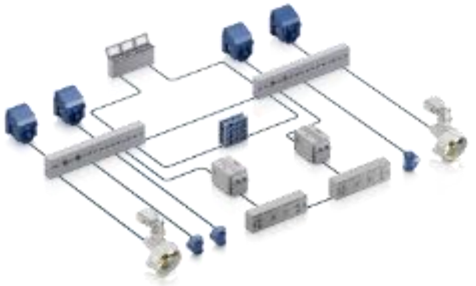
Electric propulsion is a future-proof concept

Path to improve energy efficiency and to decarbonize shipping

Electric power and propulsion systems as a backbone of electric and hybrid vessels



Up to 27% reduced fuel consumption with DC solutions



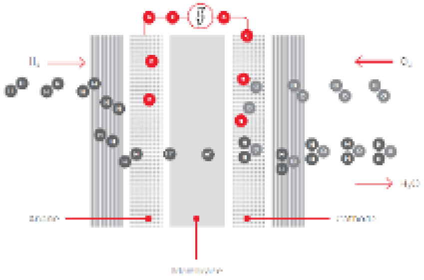
Azipod® electric propulsion

Additional 10% increased energy efficiency with Azipod® electric propulsion

Energy storage

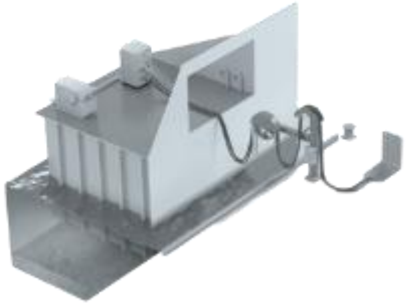
Hybrid or fully electric operation with stored energy and charging solutions

Fuel cells



Zero-emission operation with hydrogen fuel cell power system

Shore connection



98% + greenhouse gas emissions eliminated in port call

Well to Wake: Outlook

Benefits and Challenges

Path from Well to Wake for Green Ammonia

Well (NH3)

- ↗ Massive global green production potential
- ↗ Possible eventual pink production
- ↗ Virtually endless supply with H2 from sea and N2 from sky

Storage Aboard (NH3)

- ↘ Requires modest cooling (-33C) or pressure (15 bar)
- ↘ 3.6x volume of VLSFO
- ↘ 2.2x weight of VLSFO
- ↘ Safety challenges

Distribution (NH3)

- ↗ Currently world's 2nd most produced chemical
- ↗ Existing gas vessels
- ↗ Existing trading networks
- ↗ Existing standards

Wake (NH3)

- ↗ Use in slow speed diesel engine or SOFC (all under development)
- ↗ Ammonia 99%+ purity yields highly predictable performance
- ↘ Requires a pilot fuel

Green Ammonia

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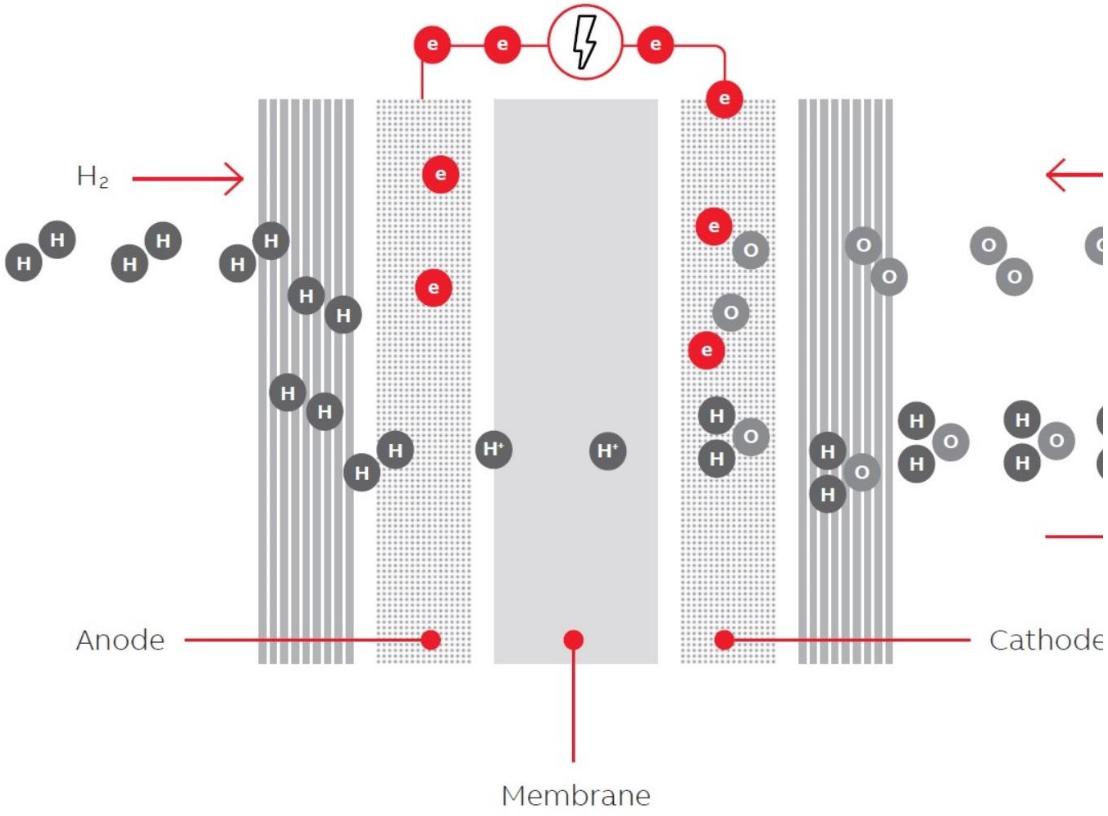
Maritime Partners – Hydrogen One

Methanol Fuel Cell Towboat



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Ammonia Opportunities Inland Waterways

Speaker: Jan Flores, Vice President

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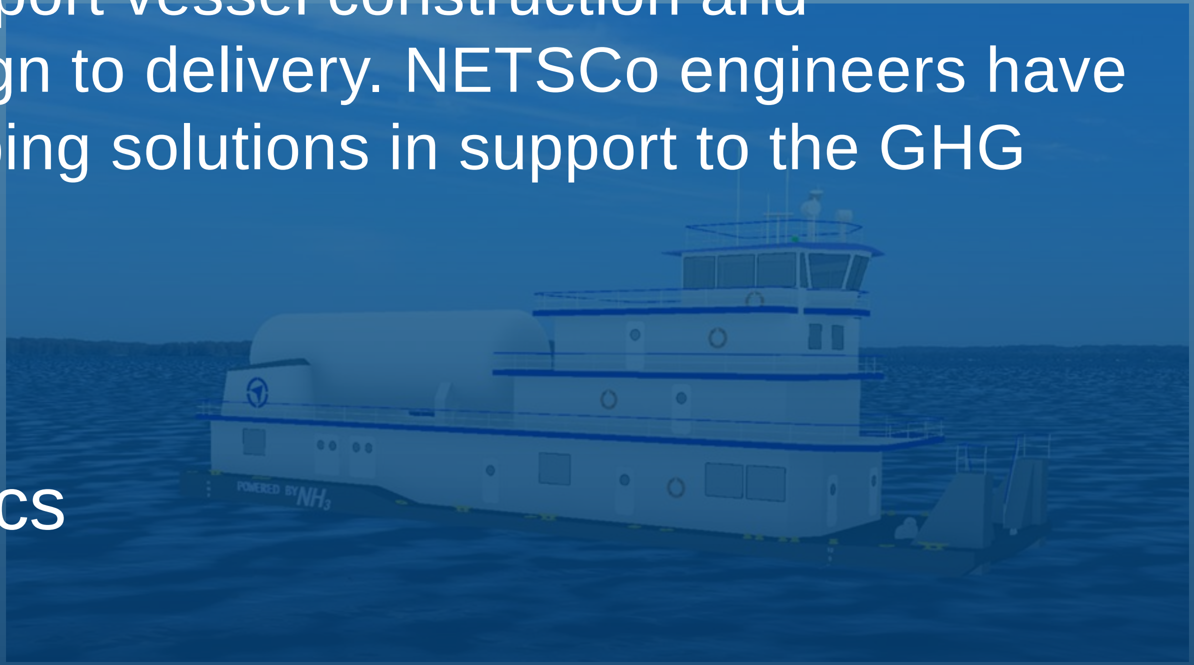
Cleveland, Ohio | Tampa, Florida

Northeast Technical Services Co., Inc. (NETSCo) was formed in 1984. NETSCo offers a broad range of naval architecture and marine engineering services to support vessel construction and modifications from conceptual design to delivery. NETSCo engineers have taken a dedicated focus on developing solutions in support to the GHG reduction.



Agenda

- US Inland Waterways Statistics
- US Emissions Regulations
- Ammonia Supply Infrastructure
- Applications /Hydrogen Carrier

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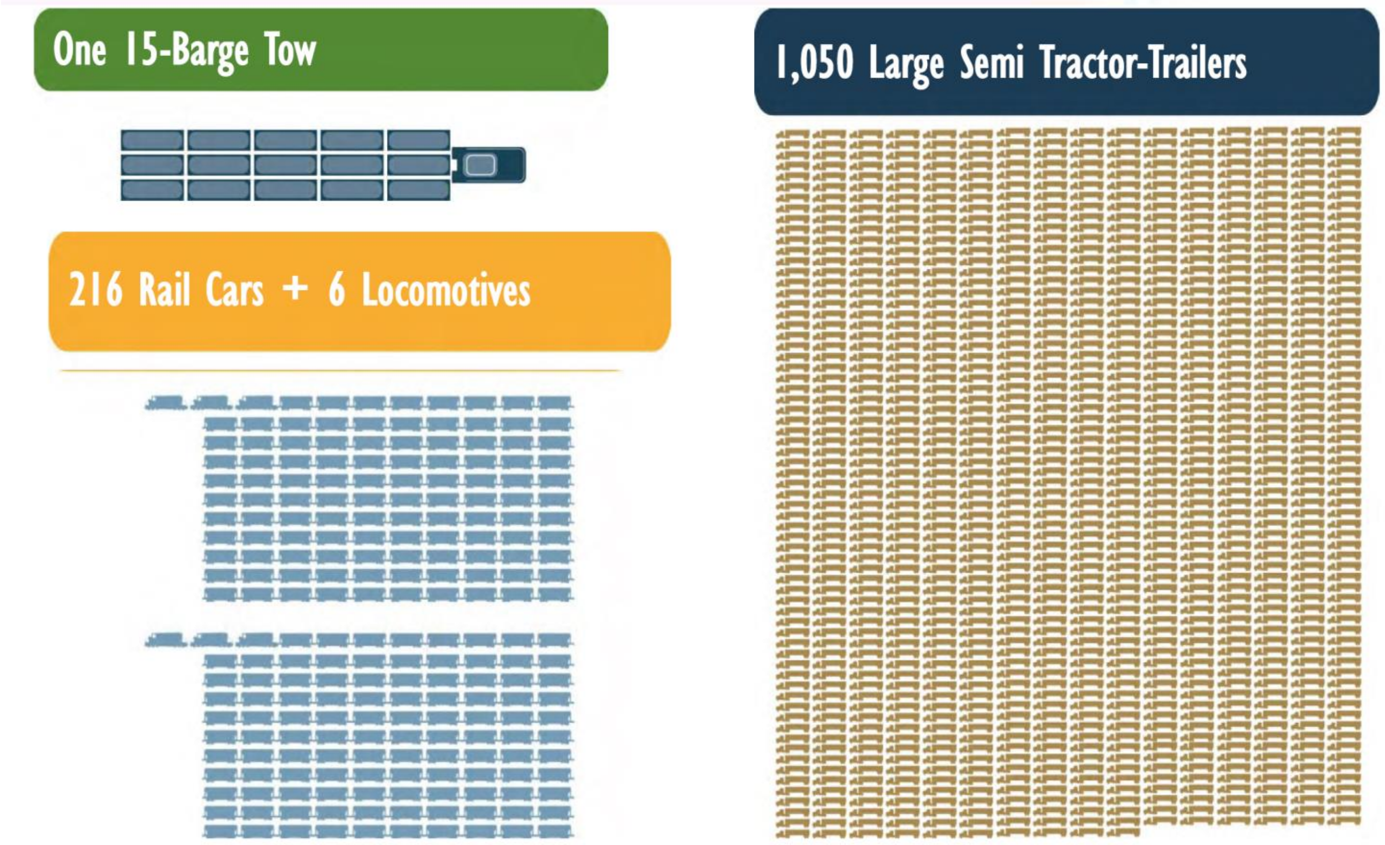
Inland Waterways Transportation Statistics

- Waterway Transportation 578 Million Tons
- Barge Tow – Ton-Mile 41 USG
- Rail Cars Ton-mile 57 USG
- Trailers Ton-mile 186 USG
- 5,500 towboats/tugboats
- 6.2 million tons CO_2

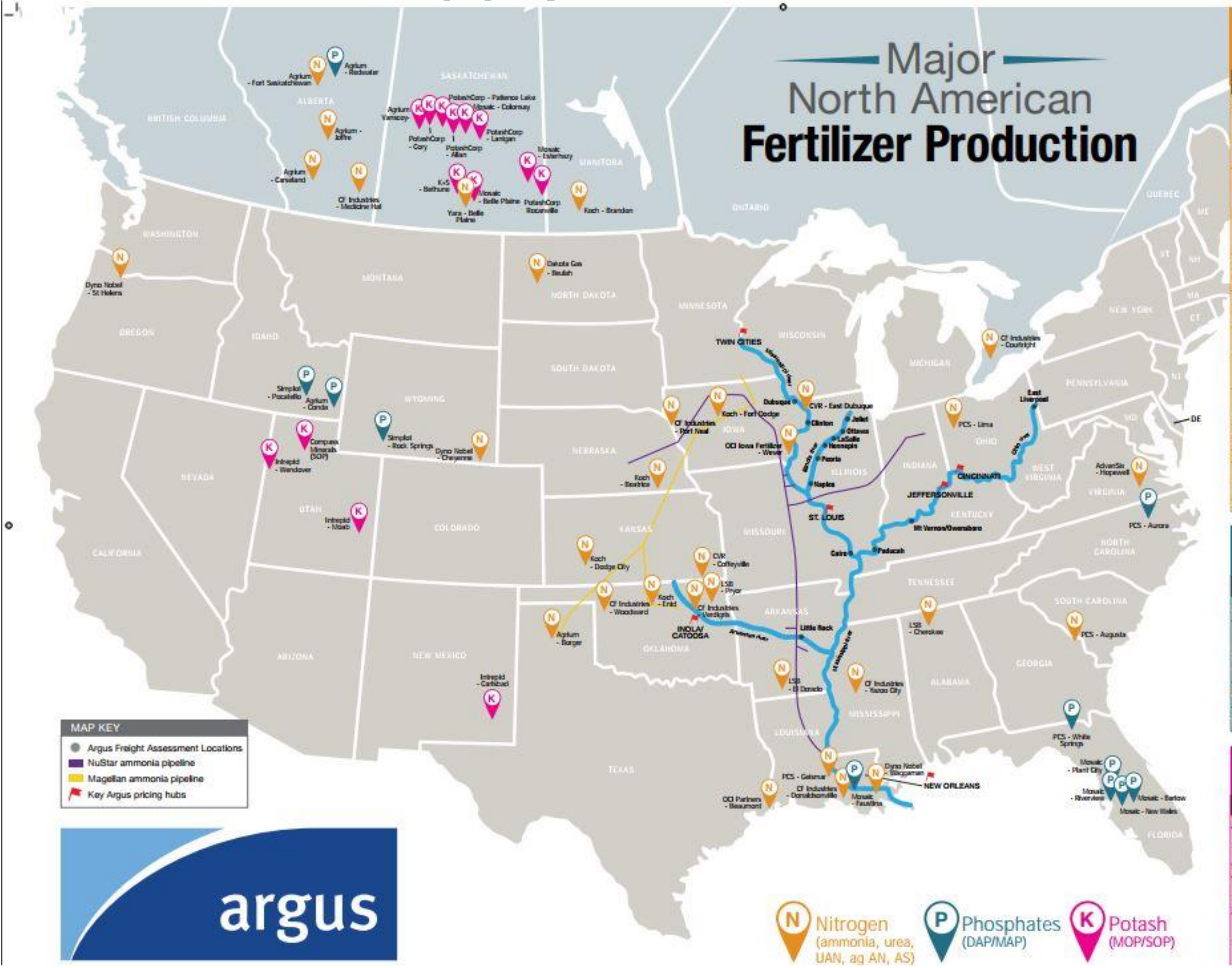


Source: The American Waterway Operators

US Adopting IMO 2050 GHG Strategy

- MARPOL is applicable to vessel over 400 GRT, but most US Towboats don't carry MARPOL Certificates.
- OFTEN MARPOL aligns with EPA, but EPA has specific requirements.
- EPA Marine Emissions Regulations followed Over the Road regulations (e.g., EPA Tier 3 & EPA Tier 4 [IMO Tier III])
- Clean Shipping Act of 2022 basically tries to align US with IMO 2050.
- On August 5, 2021, EPA announced plans to reduce greenhouse gas (GHG) emissions with 2050 – 0 emissions target from over the road vehicles through a series of rulemakings over the next three years. The first rulemaking finalized on Dec 2021.

Ammonia Supply Infrastructure US



Nitrogen

AMMONIA/UREA/UAN PLANTS		CAPACITY ('000 st/yr)				
COMPANY	LOCATION	AMMONIA	UREA	UAN	AN	AS
AdvanSix	Hopewell, Virginia	513				1,800
Agrium	Redwater, Alberta	3,095	2,808	198	276	391
	Carseland, Alberta					
	Joffre, Alberta					
	Fort Saskatchewan, Alberta					
	Borger, Texas					
CF Industries	Donaldsonville, Louisiana	9,555	5,300	7,325	1,035	
	Medicine Hat, Alberta					
	Port Neal, Iowa					
	Verdigris, Oklahoma					
	Woodward, Oklahoma					
	Yazoo City, Mississippi					
	Courtright, Ontario					
CVR Partners	Coffeyville, Kansas	866		1,497		
	East Dubuque, Illinois					
Dakota Gas	Beulah, North Dakota	420				146
Dyno Nobel	Cheyenne, Wyoming	1,173	221	282		
	St Helens, Oregon					
	Waggaman, Louisiana					
Koch	Fort Dodge, Iowa	2,824	1,799*	1,496		
	Dodge City, Kansas					
	Beatrice, Nebraska					
	Enid, Oklahoma					
	Brandon, Manitoba					
LSB	Pryor, Oklahoma	909		614	300	
	Cherokee, Alabama					
	El Dorado, Arkansas					
Mosaic	Faustina, Louisiana	565				
OCI Iowa Fertilizer	Wever, Iowa	690	690	1,405		
OCI Partners	Beaumont, Texas	331				
PotashCorp (PCS)	Augusta, Georgia	2,340	1,059	1,659		
	Geismar, Louisiana					
	Lima, Ohio					
Yara	Belle Plaine, Saskatchewan	764	1,207	288		

Phosphates

COMPANY	LOCATION	DAP/MAP/MES/FEED CAPACITY ('000 st/yr)
Agrium	Redwater, Alberta	1,000
	Conda, Idaho	
Mosaic	Bartow, Florida	12,896
	New Wales, Florida	
	Riverview, Florida	
	Plant City, Florida	
	Faustina, Louisiana	
PotashCorp (PCS)	Aurora, North Carolina	2,095
	White Springs, Florida	
Simplot	Pocatello, Idaho	1,150
	Rock Springs, Wyoming	

Potash

COMPANY	LOCATION	MOP (KCl) CAPACITY ('000 st/yr)
Agrium	Vanscoy, Saskatchewan	3,333
Intrepid	Carlsbad, New Mexico	390
	Moab, Utah	
	Wendover, Utah	
K+S	Bethune, Saskatchewan	2,205
Mosaic	Colonsay, Saskatchewan	12,896
	Belle Plaine, Saskatchewan	
	Esterhazy, Saskatchewan	
PotashCorp (PCS)	Allan, Saskatchewan	18,850
	Cory, Saskatchewan	
	Lanigan, Saskatchewan	
	Patience Lake, Saskatchewan	

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Fuel Parameters Comparison

	MGO	LPG (Propane)	LNG	Methanol	Ammonia	Hydrogen
Boiling Point (amb) - C	Liquid	-42	-162	Liquid	-28	-253
Energy Density (MJ/kg)	47.2	46	50	19.9	18	120
Energy Density (GJ/m3)	35.9	25.3	23.4	15.8	12.7	8.5
Carbon Fuel Coefficient (CO2/F)	3.206	3.000	2.750	1.375	0	0

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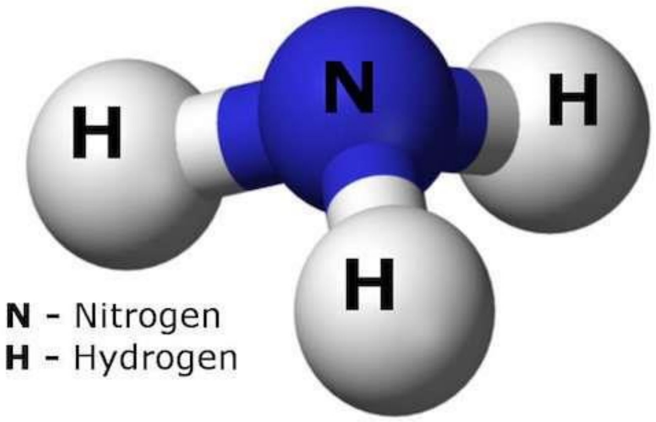
Ammonia (NH_3) as a Hydrogen (H_2) Carrier

- NH_3 molecular composition will pack 45% more hydrogen per unit volume than H_2
- 85% efficiency H_2 extraction
- Ammonia storage and transport regulations (Class) are fully developed – Fuel regulations in progress



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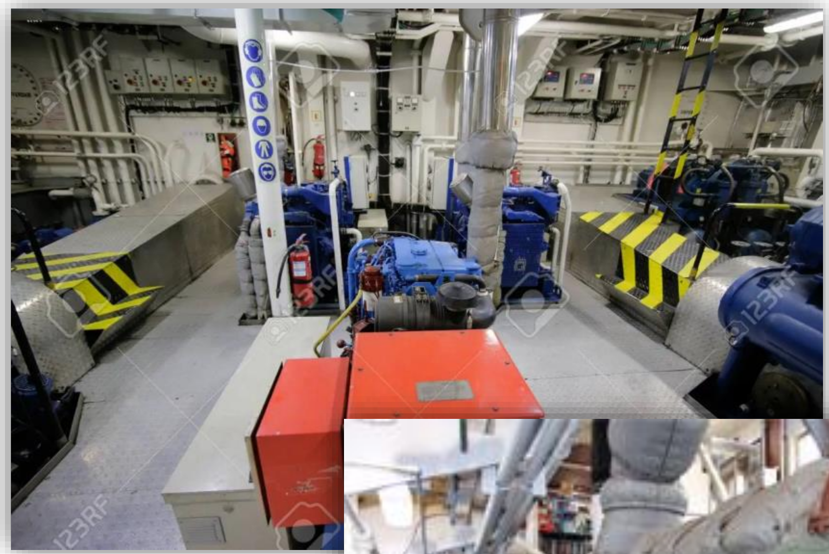
Towboat Propulsion Arrangement

- Traditionally fitted with 2 to 3 Med (900 rpms) to High Speed (1600 rpms) diesel engines.
- High horsepower med-speed is preferred and there is a large number of 2-stroke EMD engines in the water ways.
- Reduction Gear ➡ Tailshaft ➡ FFP



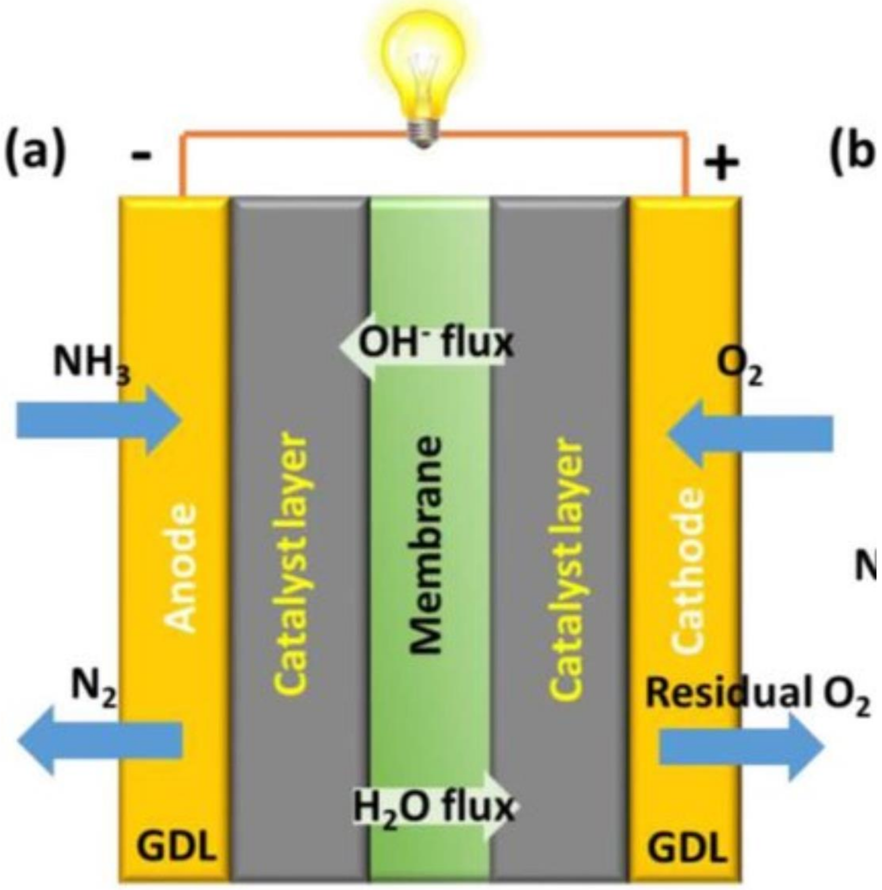
How do we us Ammonia as fuel?

➢ **Internal Combustion Engine (ICE) Route**

- NH_3 injection in diesel ICE ➡ Increase in NOx
- H_2 injection in diesel ICE has many advantages requires ➡ system to crack ammonia.
- Ammonia fuel ICE Wartsila 4 stroke under development ➡ reduce range NOx abatement.

➢ **Fuel Cell Route**

- PEM fuel cells ➡ electrification ➡ cracking NH_3
- SOFC ➡ electrification ➡ directly feed NH_3 ➡ not commercially available yet.



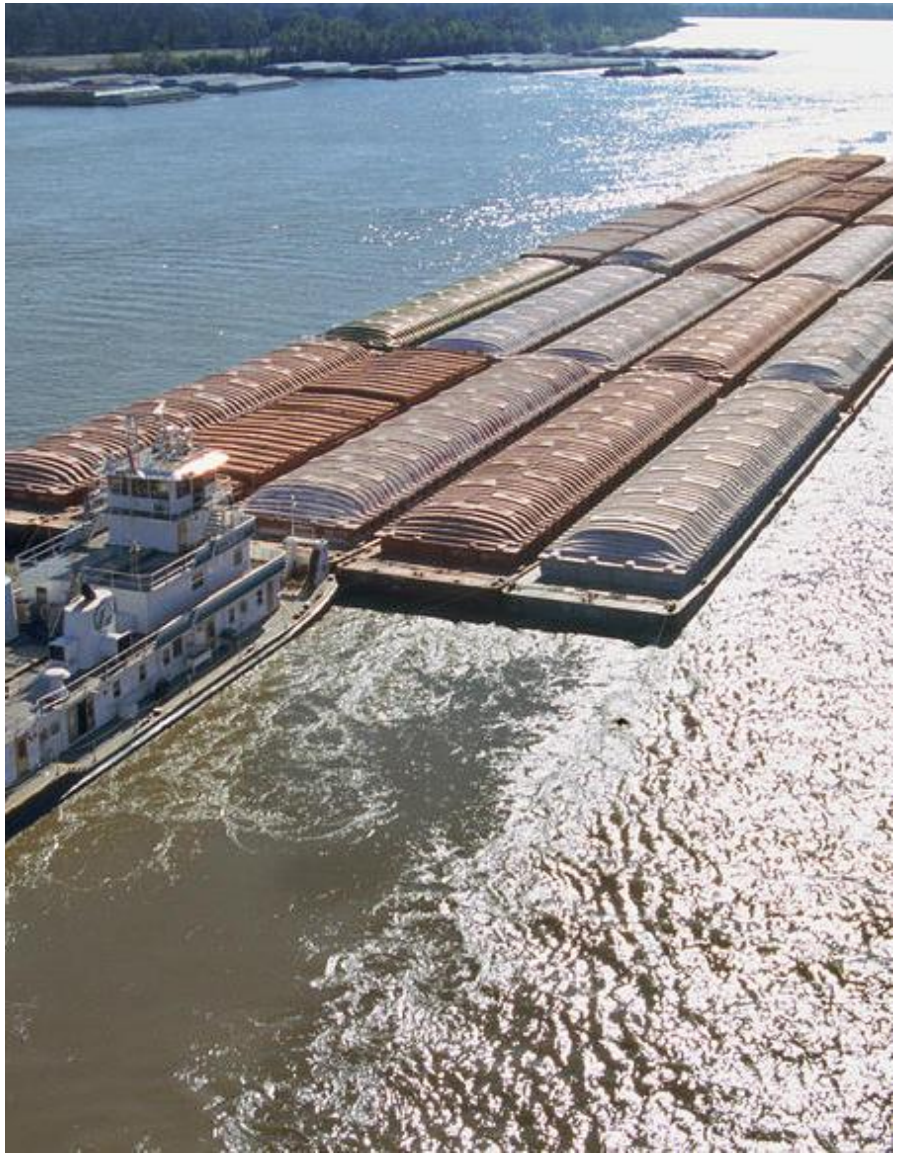
Anode: $2NH_3 + 6OH^- \rightarrow N_2 + 6H_2O + 6e^-$

Cathode: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

Overall: $4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O$

Take aways

- Waterborne transportation within waterways more efficient than Rail and Over the Road.
- Waterways transportation Carbon footprint is large with opportunities for reduction.
- No current GHG emissions regulation for Marine Inland Waterways transportation.
- Expect the forthcoming Over the road GHG regulations will spill over Marine.
- Ammonia storage a mature technology.
- Ammonia is an efficient method of Hydrogen Storage.
- Ammonia burning ICE is being developed but inefficient.
- Ammonia burning SOFC is promising but development lags.



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- Environmental Regulatory Compliance
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