NOVEMBER 2023

THE INVESTMENT CASE FOR CCS

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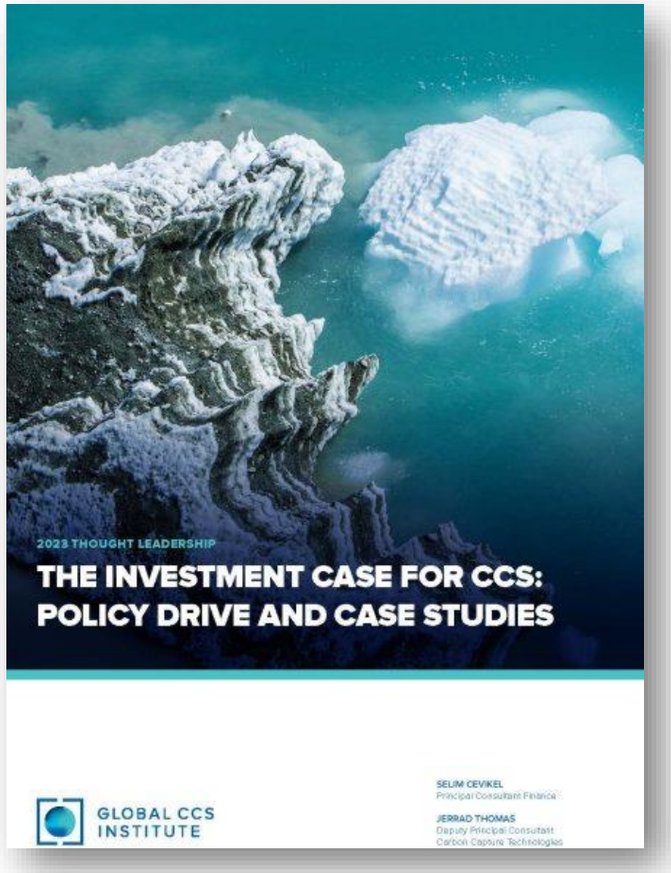
KEY TAKEAWAYS

- Policy and regulation are the only drivers of the economic value of CCS
    - Recent policy drive enables attractive returns
- Effective (implicit) carbon price range: $100 to $200
- Case studies in this report:
    - Clean hydrogen/ammonia with CCS
    - CO_2 pipelines with ethanol as the backbone,
    - CCS in power generation
- Opportunities: Attractive returns, proving the efficacy of CCS, driving down cost function, paving the way for mandates
- Risks: Permitting, execution, implementation



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CCS : AN ABATEMENT TECHNOLOGY

- Capture is a process to remove CO_2 at the point of generation.
- The point of generation: an industrial process, exhaust from fossil fuel combustion, a chemical reaction, separated from produced gas and petroleum, or any other source where CO_2 is a byproduct.
- At the scale needed for decarbonization, CO_2 will be injected permanently underground.
- CCS LIKE ALL INFRASTRUCTURE IS CAPITAL INTENSIVE
- Economies of scale
- High capture rate and high-capacity utilization = lower unit cost

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ECONOMIC VALUE OF CCS

Positive when and if

$$MC_{emissions} > MC_{abatement}$$

Equation can only be changed through policy and regulation

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POLICY TOOLBOX

Policy tool	Mechanism	Potential to drive demand for CCS
Carbon markets (cap and trade or baseline)	Increases the cost of emissions	Up
Carbon tax	Increases the cost of emissions	Up
Subsidies/grants/loans for abatement	Decreases the cost of abatement	Up
Command and control	Mandates abatement	Up

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THE UNITED STATES

- Policy tool: production tax credits and low-cost loans
- 2021: IIJA (Bipartisan Infrastructure Law)
- 2021: DOE Office of Fossil Energy adds "Carbon Management" to their name
- August 2022: The Inflation Reduction Act
  - 45Q : $85 for tonne of CO_2 – up from $50 - $180 for DAC (12 years)
  - 45V: up to $3kg per kg of Clean hydrogen production (10 years)
  - 45Z: 2 cents per gallon of clean fuel (ethanol) (2025-2027)
- Title 17 – DOE – LPO Loans and Loan Guarantees
- Proposed EPA Rule: prospect of "command and control"
- States: LCFS markets

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THE EUROPEAN UNION

Policy tool : EU ETS

- Dates back to 2008
- But too many free allowances

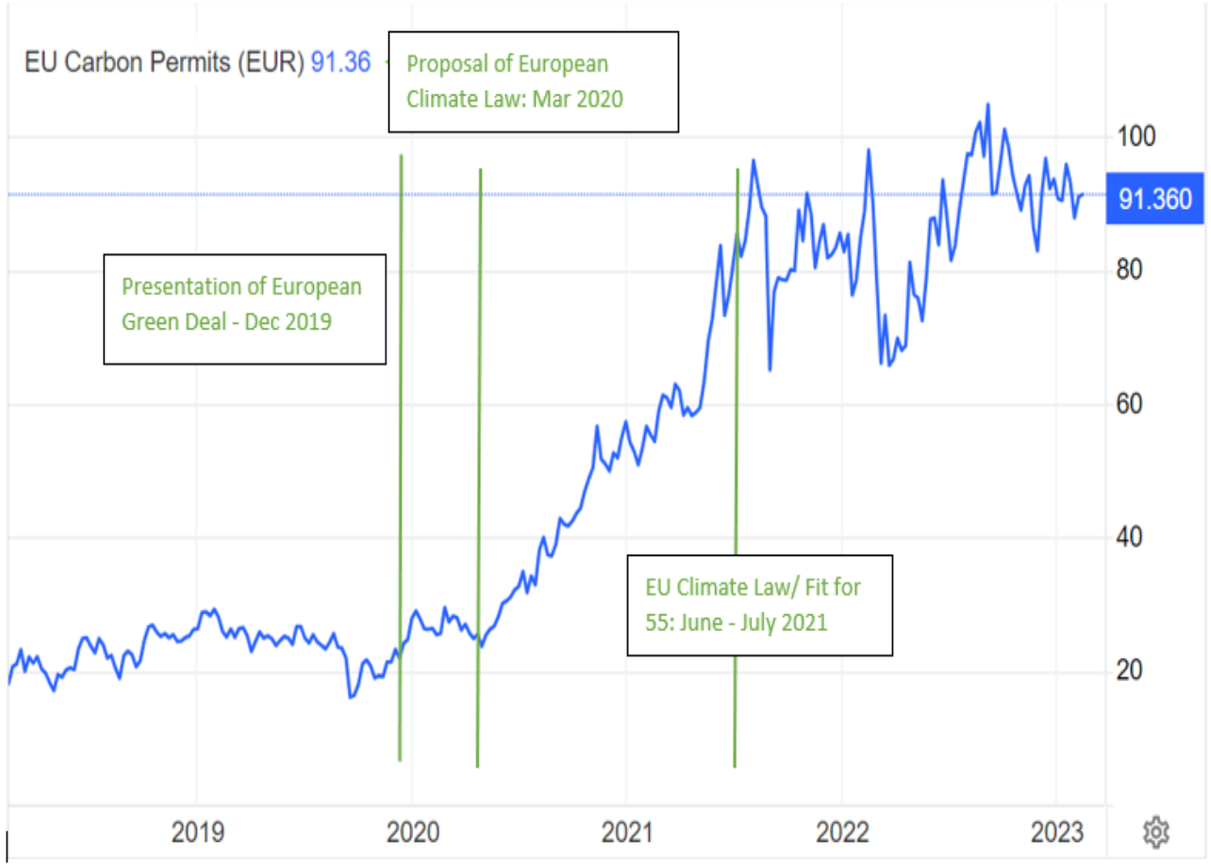
European Green Deal

Fit for 55

2023 reforms:

- CBAM
- Elimination of free allowances
- Maritime
- Aviation
- CCfD (Contracts for Diff)

EU ETS price chart dated 15 August 2023.



Source: Trading Economics, 2023

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JAPAN AND SOUTH KOREA

- Policy tool: Demand subsidies / experimentation with carbon pricing
- Energy and sequestration geology constrained
- Japan: $107 bn for clean hydrogen infrastructure
- Japan: First ammonia offtake
- Korea: Heavy focus on clean hydrogen projects
- Early beginnings of carbon pricing (South Korea, Singapore, Japan)

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CLEAN AMMONIA IN THE U.S.

- Clean hydrogen/ammonia: critically important component of energy transition
- Revenue streams (US): 45Q or 45V production tax credits
- Revenue streams (International): Carbon pricing in the EU, subsidies in Japan and South Korea on the demand side add to returns
- Total carbon price tantamount to close to $200 through stacking
- Currently, there is no domestic demand; all projects are for export markets
- Potential EPA power plant rule would serve as a demand driver in the US

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CLEAN AMMONIA IN THE U.S.

Drivers for project economics

- Abundant and cheap natural gas
- Suitable geology for CCS
- Pipeline infrastructure
- Export infrastructure
- Export demand
- Policy support and conviction

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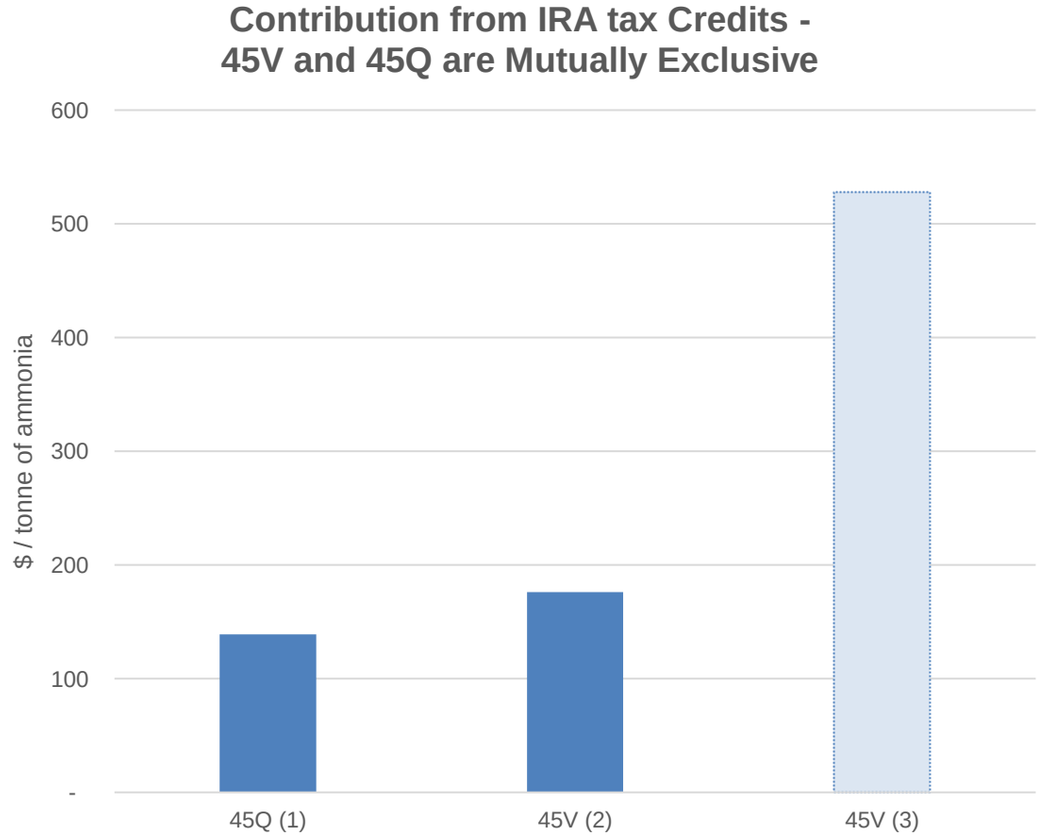
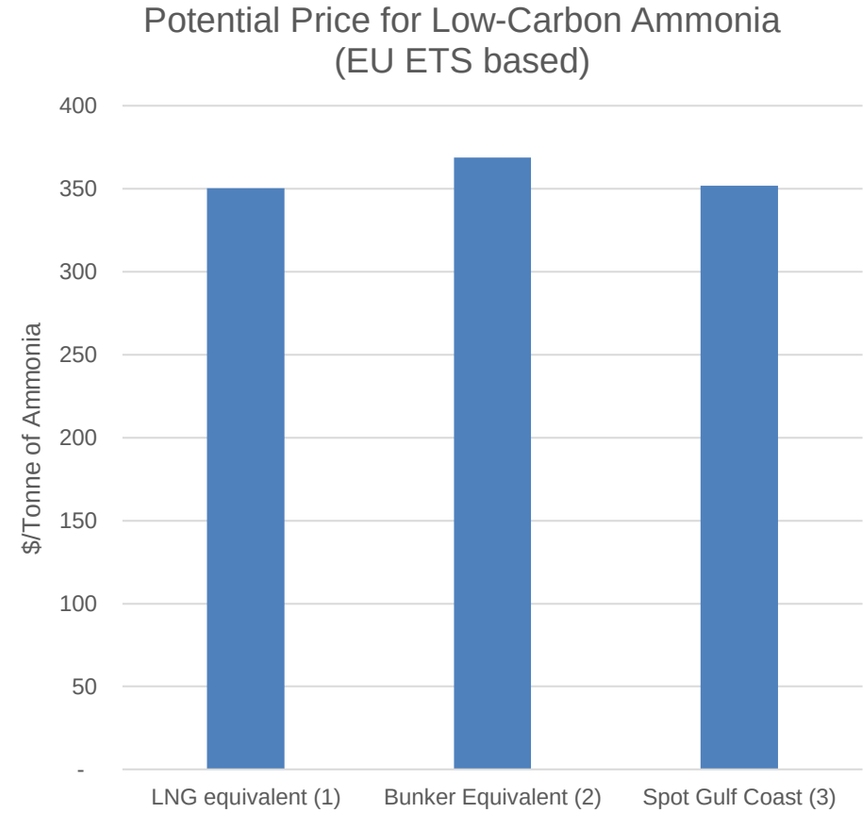
CLEAN AMMONIA IN THE U.S.

Revenue Streams





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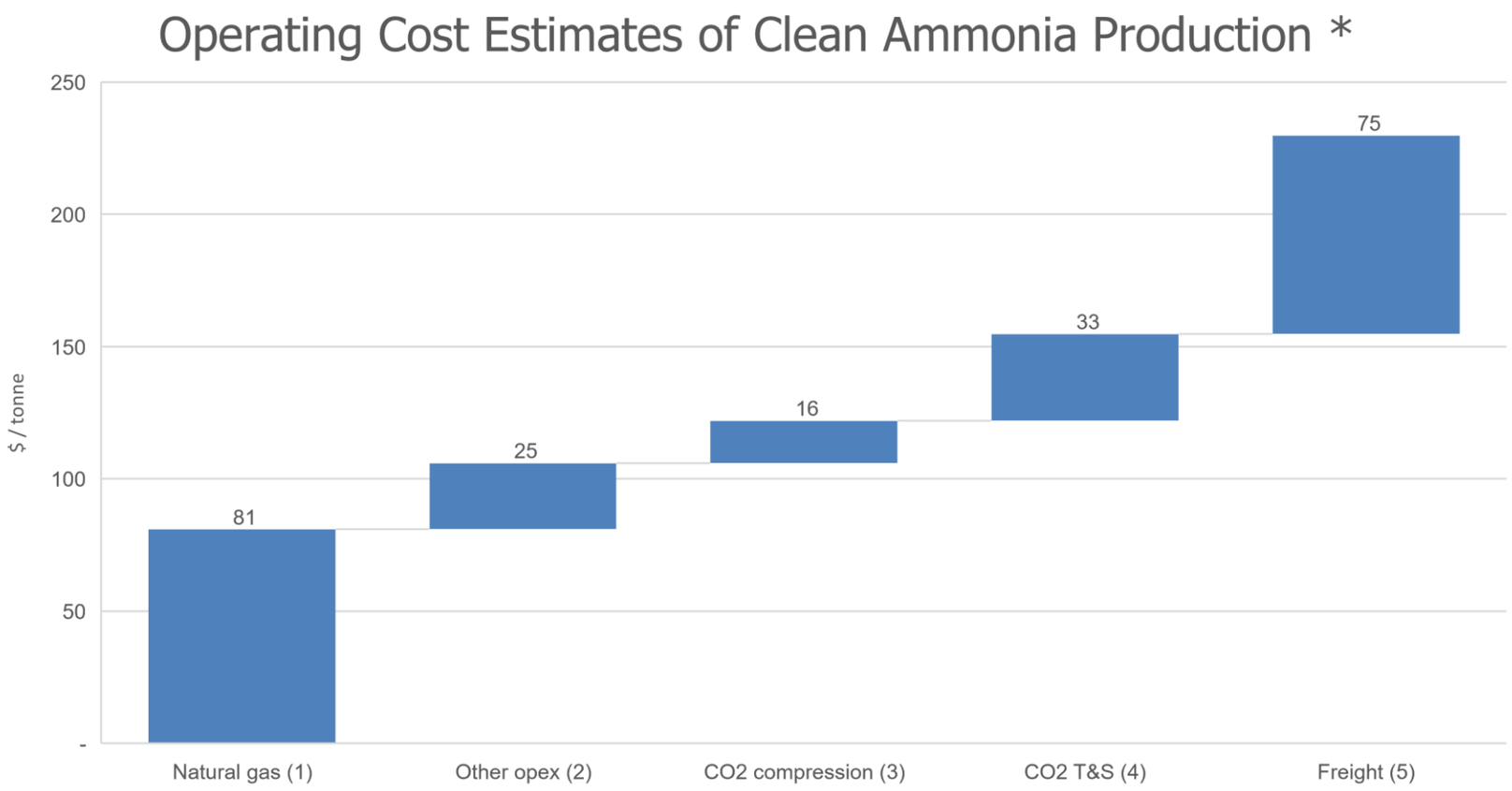
CLEAN AMMONIA IN THE U.S.



- Capital expenditure range : $1,400 to $2,100 per tonne
- IRR : Based to 10-year 45V - 10.2% to 17.4%

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CLEAN AMMONIA IN THE U.S.

Announced projects (capital costs range from $1,400 to $2,100 per tonne of NH_3

Project:	Product	Location	Capacity *	Completion	Target Market
CF/Lotte/Mitsui	Ammonia	Blue Point LA	1.2	2030	Korea
CF/Exxon	Ammonia	Ascension Parish LA	1.2	2028	Export
CF/POSCO	Ammonia	Blue Point LA	1.2	2028	Export
LSB/Impex/AirLiquide	Ammonia	Houston Ship Channel	1.2	2027	Export
Linde/OCI	Ammonia	Baumont TX	1.1	2027	Europe
Yara/Enbridge	Ammonia	Corpus Christi TX	1.4	2027	Europe
CHW/MOL/Hafnia/Den	Ammonia	Ascension Parish LA	7.2	2027	Europe
Mitsubishi/Lotte/RWE	Ammonia/Hydrogen	Corpus Christi, TX	10.0	2030	Asia/Europe
CRC/Brookfield	Ammonia	Northern CA	0.2	2027	California
Air Products	Hydrogen/Ammonia	Ascension Parish LA	1.4	NA	Export
Exxon / SK Materials	Hydrogen/Ammonia	Corpus Christi TX	6.0	NA	Asia
Copenhagen IP/SFG	Ammonia	St. Charles Parish	5.0	2027	Europe
Total			~ 37		
GCCSI Analysis					
* Million NH3 Tonnes					

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MIDWEST CO_2 HUBS

- Business model: CCS as a service
- Multiple revenue streams (45Z, 45Q, and LCFS)
- Ethanol creates a gateway for CO_2 pipelines
- Long-term vision is to serve industrial and power emitters
- Risk factors: Potential cost overruns and permitting delays
- Lack of firm CO_2 volume guarantees by investment-grade emitters
- Calculation of the CI factor will be critical for 45Z
- Financial risk increases with the size and dependency on 45Z

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MIDWEST CO_2 HUBS

Operator	Shareholders	Investor type	Total raised ($mn)
Summit Carbon Solutions (Midwest Carbon Express)	Summit Agricultural Group TPG Rise Tiger Infrastructure Continental SK E&S	Private Equity Private Equity Private Equity Oil and Gas Energy (Korea)	1,350
Navigator CO_2 (Heartland Greenway)	Brookfield Renewables Valero	Private Equity Refinery	NA
Wolf Carbon Solutions (Mt. Simon Hub)	Canada Pension Plan Wolf Midstream	Pension Fund Midstream	NA

Operator	CO_2 pipeline length (miles)	Projected Capex ($bn)	Capacity (Mtpa CO_2)	Completion year
Summit Carbon Solutions	1,944	6.0	18	2025
Navigator CO_2	1,352-1,500	4.5	15	2025
Wolf Carbon Solutions	285	1.0	12	2025
Total	3,750	11.5	45	2025

With Navigator cancelling the other projects' chances have increased

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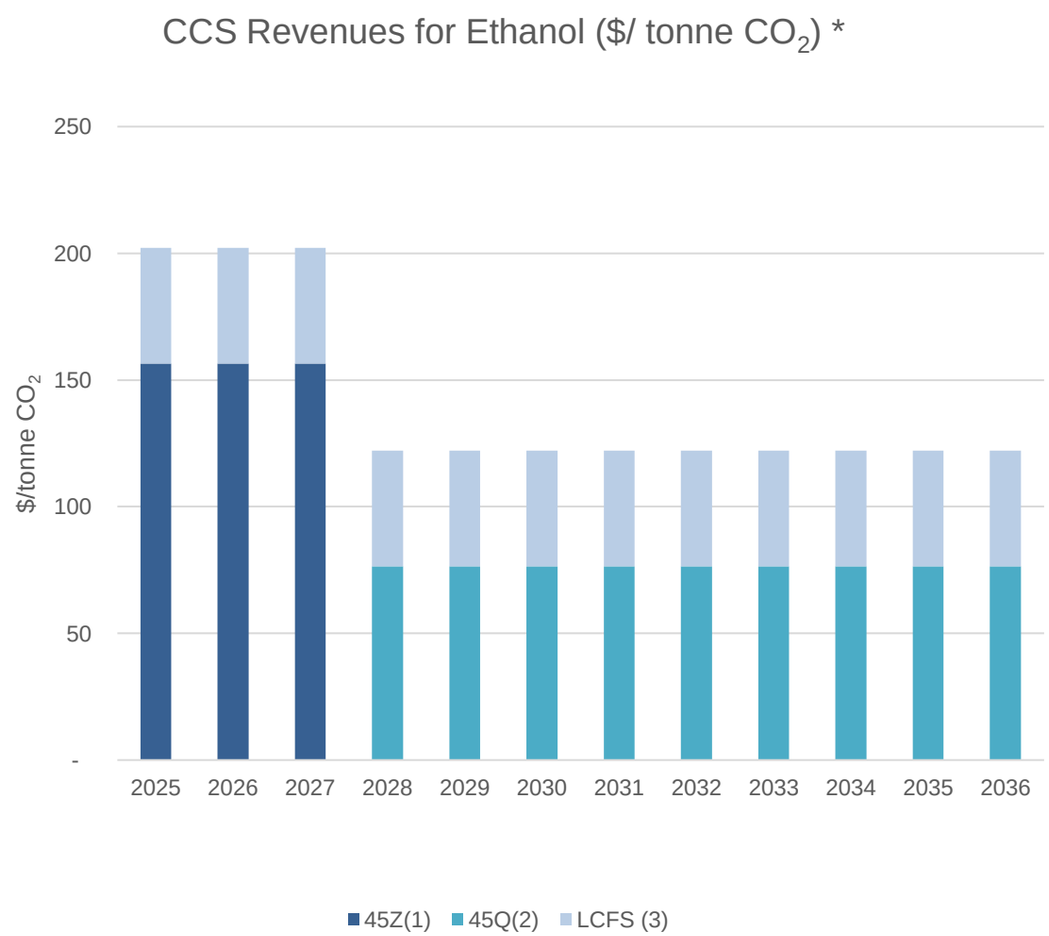
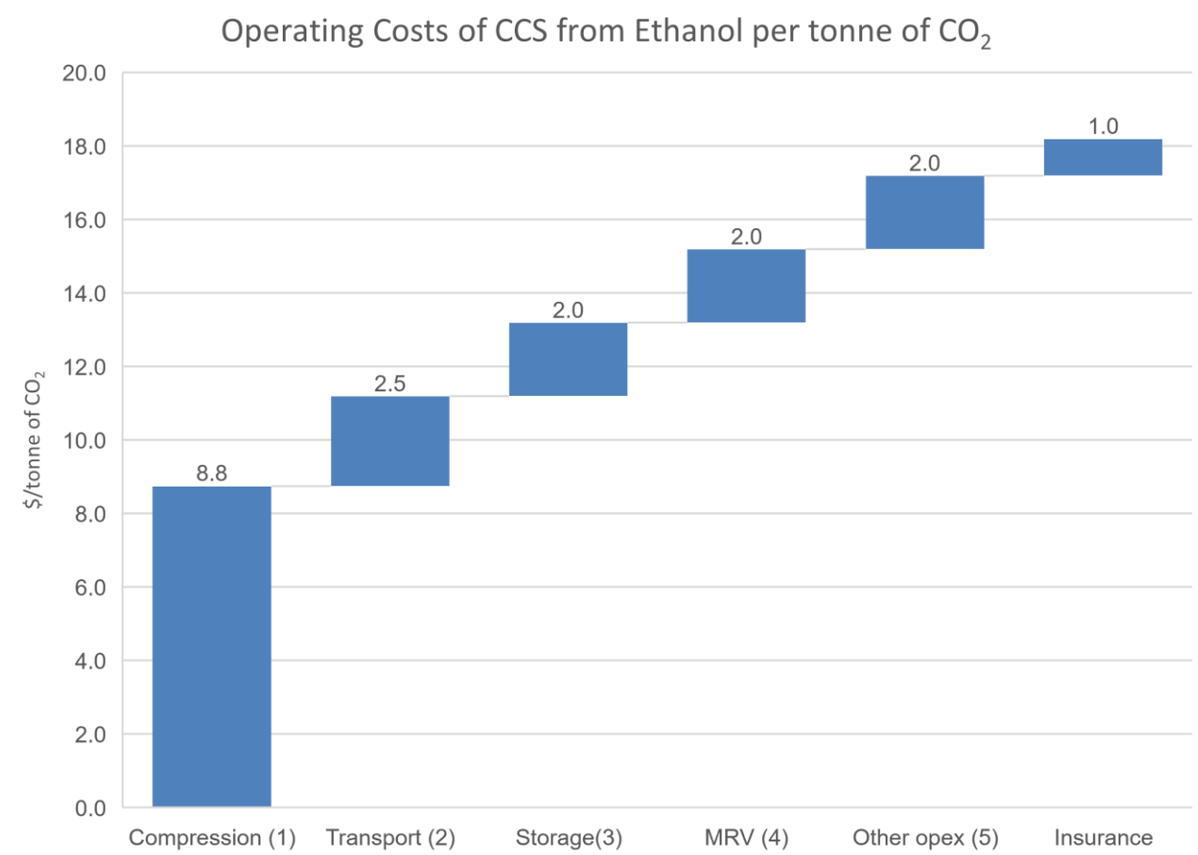
MIDWEST CO_2 HUBS





* Only part of revenues accrue to CCS operators

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CCS IN POWER GENERATION

- 45Q provides low to mid-teen returns for coal and natural gas power plants
- Attractive returns for utilities and power generators
- Caveat: If the storage is nearby
- Policy and regulatory support other than 45Q are needed beyond 12 years
- Power sector decarbonization is critical
- Technology improvements and policy support is needed for Global CCS development

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CCS IN POWER GENERATION

- North Dakota: Despite doubling wind, coal still accounts for 57% of generation
- North Dakota: Selling half of its energy to other States and Canada
- Stationary power still seen necessary for the state and neighbors
- Minnkota: Invests heavily in wind – 34% of capacity
- Minnkota: Developing Tundra since 2018
- Minnkota: Owns three of the largest Class VI wells (capacity 225 mnt)
- IRA 45Q boost enables the project to proceed
- Already secured $250 mn low-cost loans

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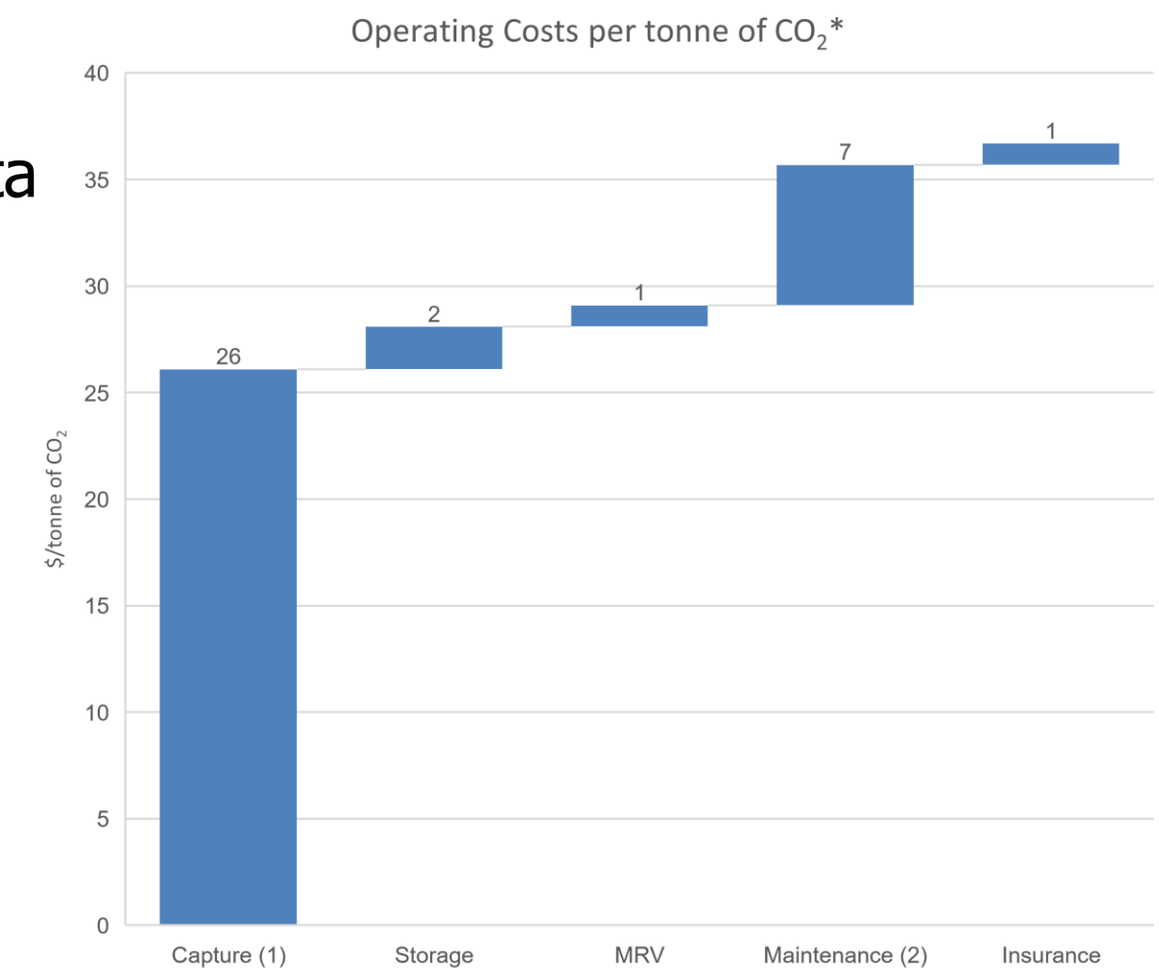
CCS IN POWER GENERATION

Hypothetical Financial Analysis

- Loosely based on publicly available data associated with project Tundra, we increased capacity utilization to 90%
- The project size to $1.67 bn
- 5.1 Mpta capture
- Nominal IRR: 10.2% unlevered 11.2% with $250mn state loan – even higher with federal grant



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CONCLUSIONS

- Strong decisive policy enables economic value and returns to CCS
- The risks include: permitting delays, execution, implementation
- Exponential increase in project announcements
- Case studies suggest attractive financial returns
- Creates opportunity for the sector to prove effectiveness and drive down the cost curve
- For the policymakers to capitalize and provide long-term incentives beyond subsidies:

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EXTERNAL COMMENTARY:
CCS IN POWER GENERATION

Cameron Hercus

CCS Development at TC Energy

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EXTERNAL COMMENTARY:
CCS IN CLEAN HYDROGEN / AMMONIA

Gonzalo Ramirez

Senior Commercial Manager at INPEX

Sean Riordan

Chief Commercial Officer at Moda

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DISCUSSION MATERIALS

November 2023

MODA

INPEX

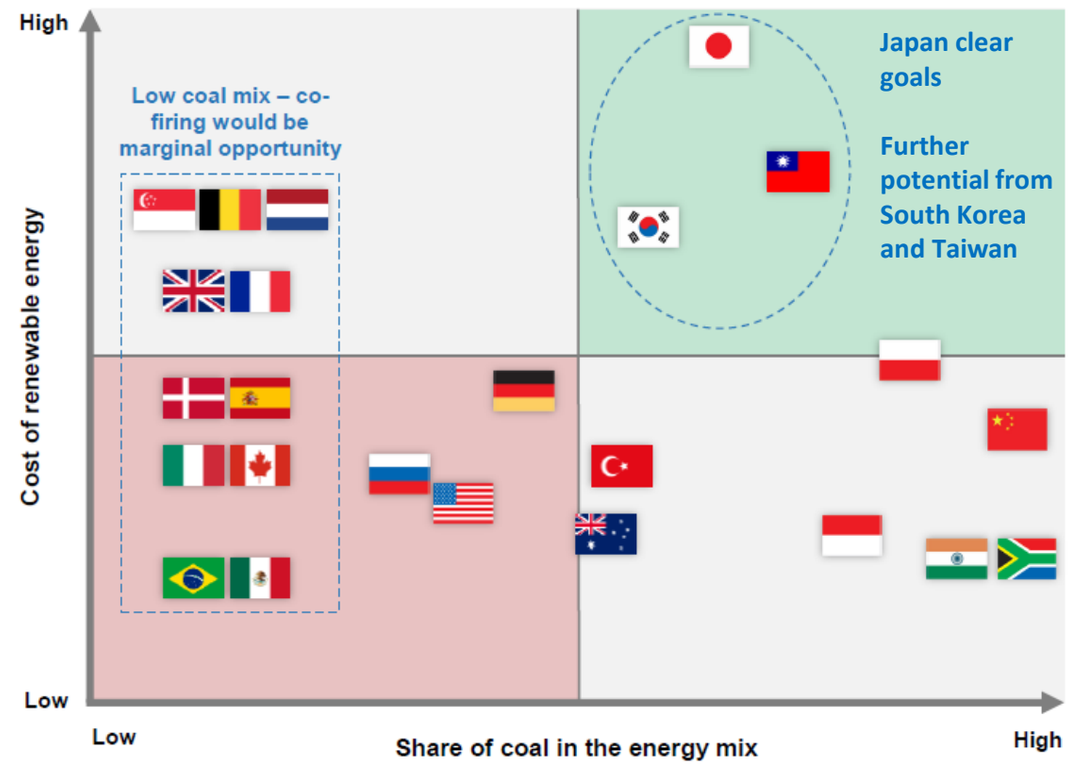
Confidential

Asian Demand Centers for Ammonia Power Generation

Primary Demand Centers

Japan	– Japanese government roadmap targets of 30 MTPA of fuel ammonia by 2050 – JERA conducted RFP for 500,000 tons and is demonstrating co-combustion of 20% ammonia – Green Innovation Fund and tax incentives estimated to induce ~$150bn private investment over next 10 years – Government will provide subsidies
South Korea	– World's seventh largest coal consumer with strong ambitions for reaching carbon neutrality – Mature ammonia infrastructure as world's fourth largest importer – Government will provide subsidies
Taiwan	– World's 14th largest coal consumer, with limited renewable options – Published Net-Zero Emissions strategy in early 2022, with a strong focus on zero-carbon energy – Coalition building for ammonia co-firing to reduce CO2 emissions

Regional Demand Dynamics for Co-Firing Opportunities



- Decarbonize existing coal-based load capacity
- Ability to continue use of relatively new fleet of power plants with long remaining life
- Research underway to demonstrate feasibility of ammonia/hydrogen blends for gas turbines

Ammonia to be used as fuel to meet decarbonization targets

Source: Yara Clean Ammonia Capital Markets presentation, IRENA – Innovation Outlook Ammonia, Mission Possible Partnership, Arkwright

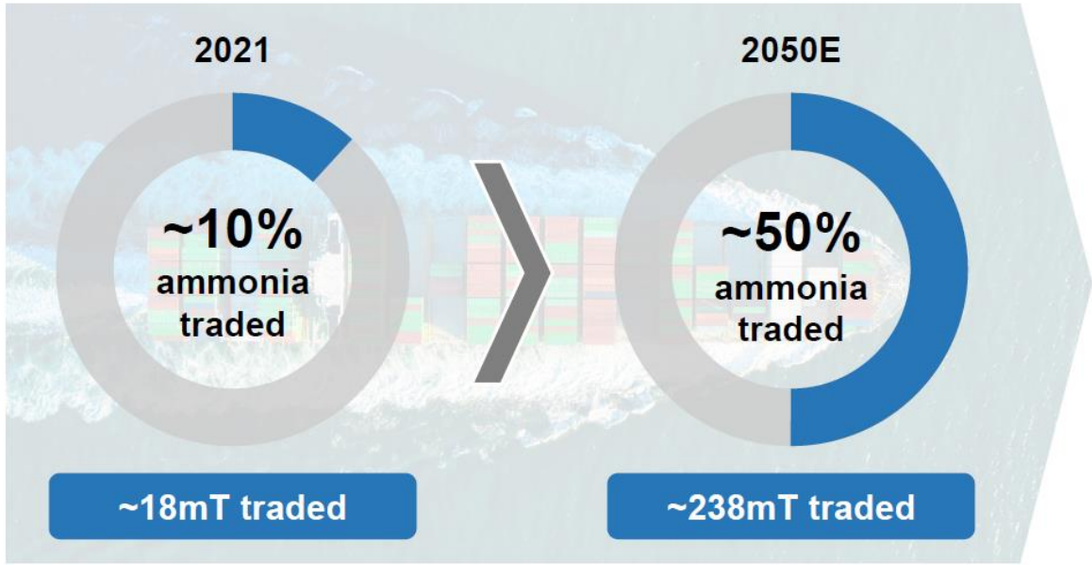
US Gulf Coast Well-Positioned to Capture Market Share

Gulf Coast Competitive Edge

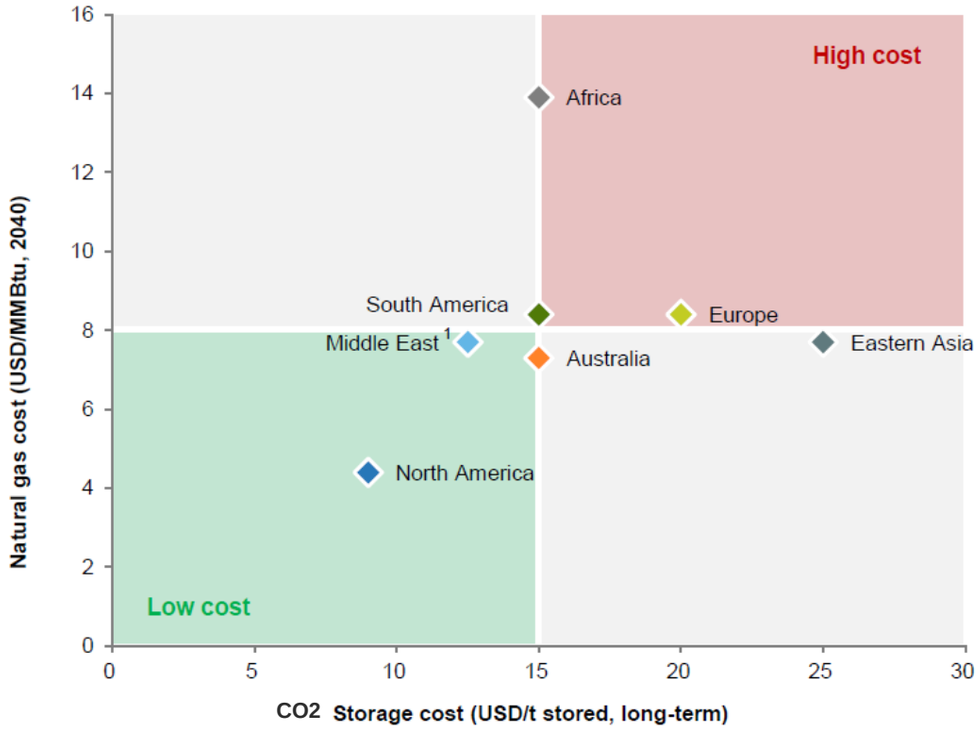
- ☑ Supply infrastructure (e.g. existing gray)
- ☑ Export infrastructure
- ☑ Industrial demand center
- ☑ Access to CO2 pipelines
- ☑ Access to renewables
- ☑ Geology for sequestration
- ☑ Ease of securing permits (relative)
- ☑ Preferential eminent domain laws
- ☑ Local and regional political stability
- ☑ Policy Tools (45Q)
- ☑ Incumbent commercial relationships
- ☑ Cheap cost of natural gas (relative)

Infrastructure | Regulatory | Economics

Waterborne Terminals Balance Supply / Demand

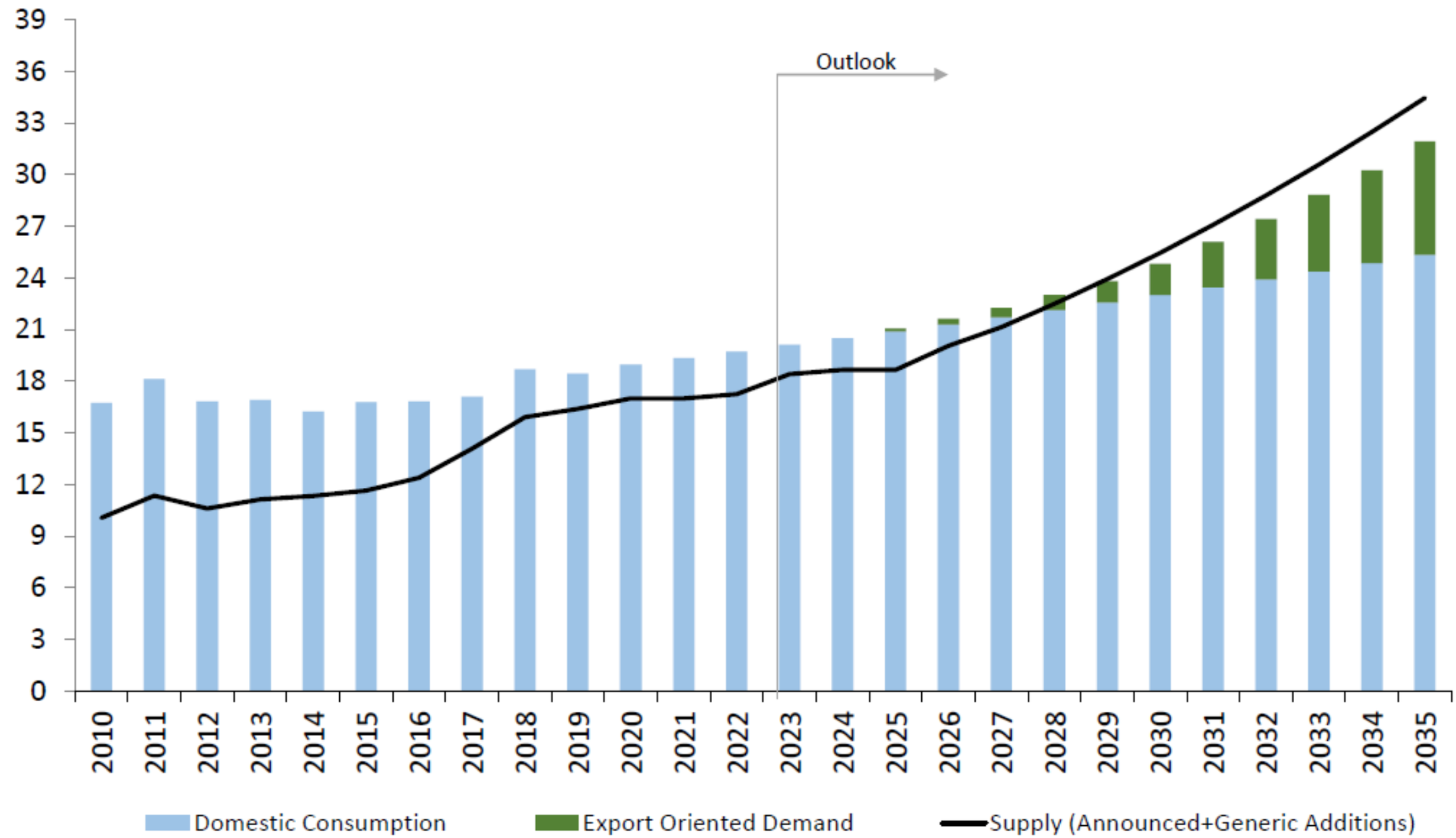


Regional Competitiveness (Blue)



Sources: McKinsey, Yara Clean Ammonia Capital Markets presentation, Arkwright market study, Argus

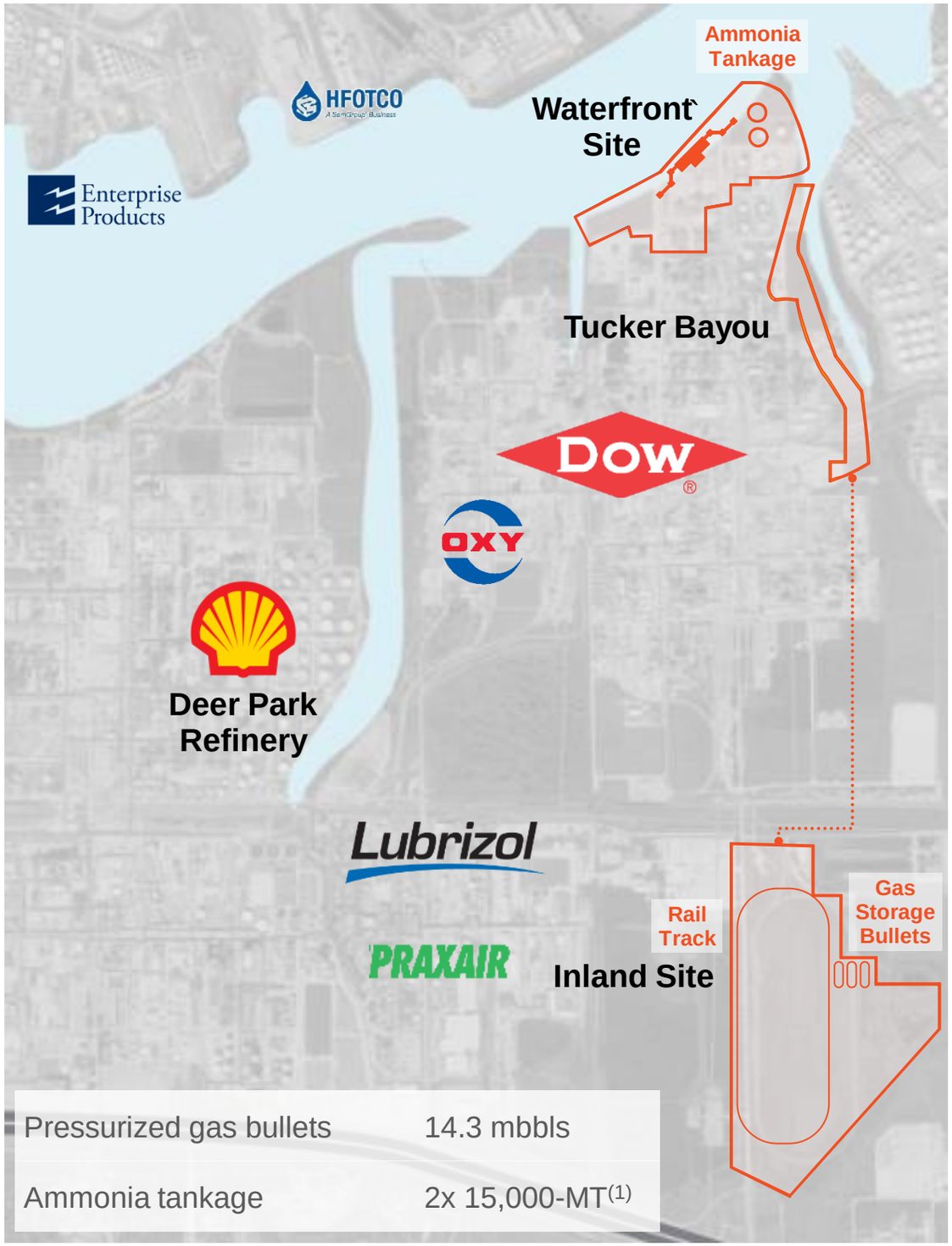
US Ammonia Supply / Demand Balance (MTPA)



Note: Supply expands by named capacity additions through 2026 then by generic capacity additions
Source; Enkon Advisors

Flagship Infrastructure in the Houston Ship Channel

- Vopak-Moda Houston is strategically located in Houston's refining and petrochemical corridor
  - Self-managed joint venture bringing together competitive advantages of each partner
- Newbuild VLGC-capable deepwater berths with ample capacity for future waterfront activities
  - State-of-the-art safety equipment
- Connected to Houston Ship Channel ammonia system and in close proximity to multiple industrial gas pipeline networks
- Modal optionality with infrastructure supplemented by existing rail loop and proximity to Houston-area petrochemical users and transport hub
- First large-scale greenfield project in the Houston Ship Channel in over a decade



Pressurized gas bullets	14.3 mbbls
Ammonia tankage	2x 15,000-MT[1]

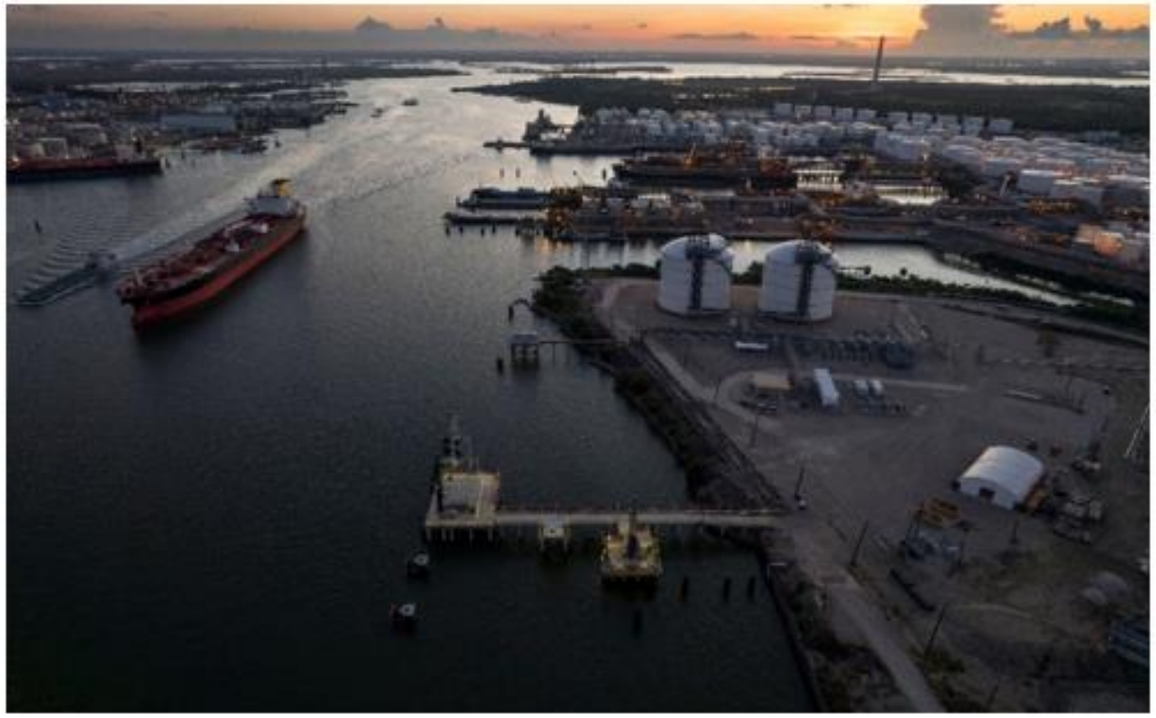
(1) MT representative of "Metric tons"

Project Shotime –Aiming 100% Ammonia Fuel to Asia

Project Highlights

1. Strong Partners professional in their field and experienced in industrial gas and ammonia production.
2. World-class infrastructure (existing terminal with permits already received, NG/H2/O2/N2 pipeline systems, NH3 pipeline to industrial users)
3. World-class location (Houston Ship Channel is the 2nd largest industrial corridor in the world and close to open water)
4. Focus on maximizing export for Japan/Korea Ammonia fuel demand (avoid commingling with fertilizer market, simplicity in commercial structure, utilizing subsidy provided by both government as much as possible, symbolic US-Korea-Japan project, does not compete with other projects focused on Fertilizer or

Houston Ship Channel Site



Project Participants

Air Liquide

- Owns and operates oxygen, nitrogen and hydrogen pipeline networks along Texas and Louisiana Gulf Coast (including world's largest H2 storage cavern in Beaumont), $91bn Market Cap.
- **H2 and N2 Producer and investor in the Project**

INPEX

- Largest E&P company in Japan
- Tokyo Stock Exchange listed $16bn Market Cap., with app. 20% held by Japanese Government, METI.
- **Investor in H2 and NH3 Facilities and major off-taker in the Project**

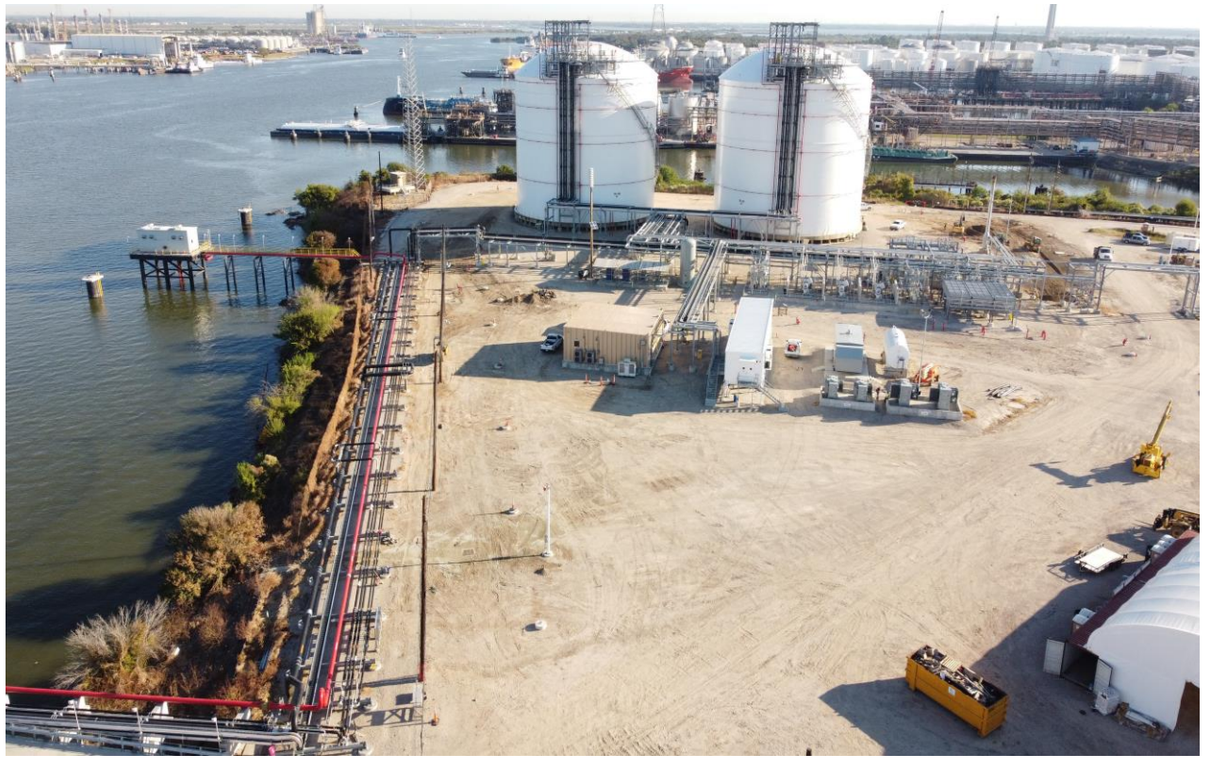
MODA

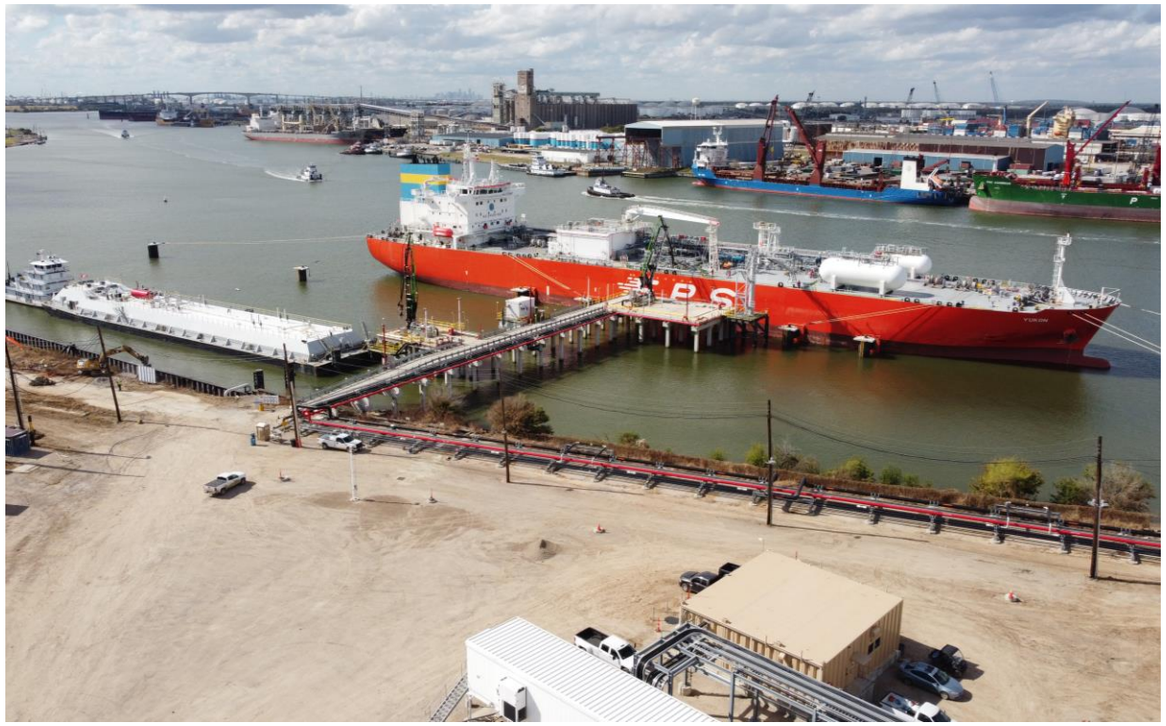
- Texas-based company that has developed and operated over $10bn of infrastructure
- History of developing first-in-kind export infrastructure for LPG, crude oil, ethanol, etc
- **Tank and Jetty owner and service provider in the Project**

LSB INDUSTRIES

- 4th largest Ammonia Producer in the US with 0.9mtpa with market cap of $1.5bn.
- **Ammonia Producer and investor in the Project (joins from FEED)**

Deer Park Marine Site Developed for Anticipated Future Expansion





PANEL DISCUSSION

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QUESTIONS?

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