Monetizing Canadian Gas through Chemicals

AIHA Canadian Petrochemical Summit,
Kananaskis

NexantECA

June 2024

Monetizing Canadian Gas through Chemicals – The market has challenges but also opportunities

1. **What can I make from natural gas?**
2. **What market opportunities are interesting?**
3. **What are some major strategic considerations?**

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Introduction and Background

NexantECA – at a glance

Company

50+ years	110+	200+
of institutional knowledge	Industry experts	projects annually

- Independent strategic viewpoint and access to unparalleled insights and proprietary data
- Segmented view of commercial, technical and environmental issues and trends that serve as headwinds and tailwinds

Clients

- Extensive experience working with all leading energy, chemicals and financial institutions
- Advised on over $150bn of investment projects, some of the largest M&A deals, and supported master planning of countries around the world
- Robust in-house data basis covering over 130 chemicals and fuels across 19,000+ operating assets globally

Our Businesses

Locations

12

countries worldwide with physical presence

What can you make from natural gas?

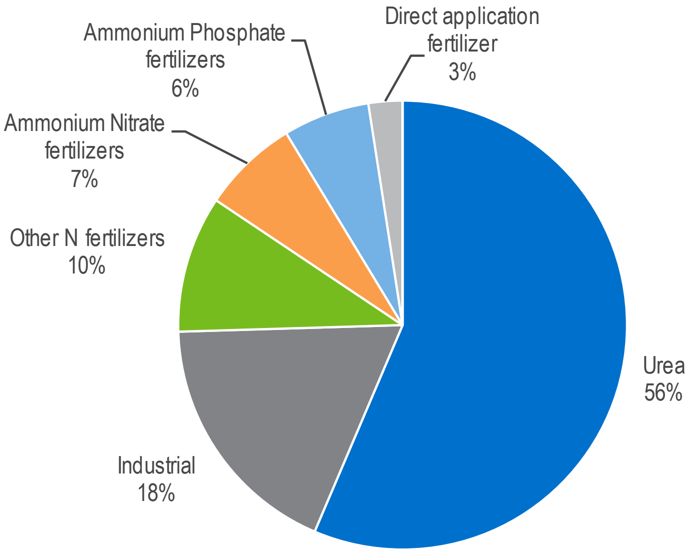
- **Heat and Power**
  - Residential
  - Commercial
  - Industrial
- **Compressed Natural Gas and Liquified Natural Gas**
  - Geopolitical strategy
- **Gas-To-Liquids**
  - Myriad derivatives
- **Methanol**
- **Ammonia/Urea**
- **Hydrogen**

Unlike lignin, good economic opportunities exist with low-cost natural gas resources

Market Opportunities - Ammonia

Ammonia and its derivatives are among the most important substances on earth

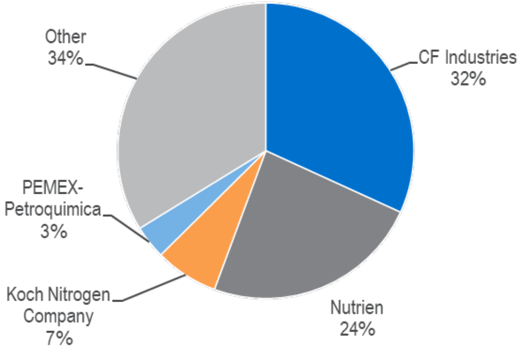
Global Ammonia Demand by End-Use, 2023-e
191.1 million tons



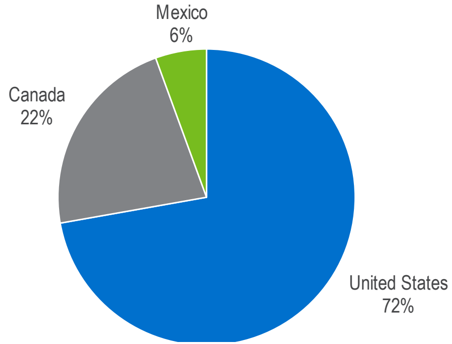
- Global ammonia consumption in 2023 is estimated to be about 191.1 million tons, an increase of four percent from 2022, driven by higher fertilizers production as global gas prices corrected
- Over 80 percent of demand goes into fertilizers, where growth is linked to population and GDP
- Increased interest and investment in sustainability (i.e., GHG emissions, other environmental implications) will challenge both the ways in which it is consumed and the ways in which it is produced
- Ammonia is increasingly being considered as an alternative to fossil fuels, thus driving the development of green (and blue) ammonia technologies

North American ammonia capacity was estimated to be 24 million tons per year in 2023

North America Ammonia Capacity Share by Marketer, 2023



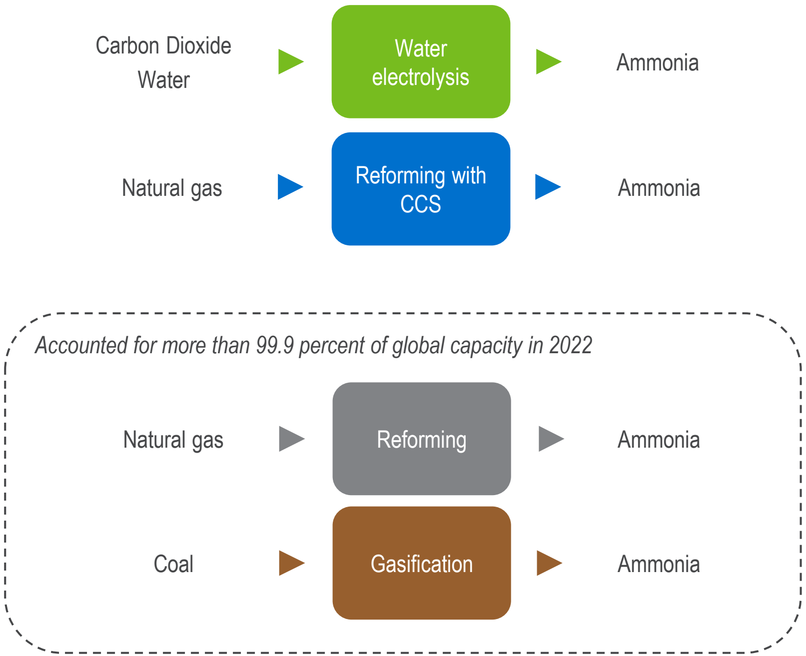
North America Ammonia Capacity Share by Country, 2023



- North America accounts for nine percent of global ammonia capacity, at just over 24 million tons in 2023
  - Koch Industries Fort Dodge (2023), expansion of 85,000 tons to 435,000 tons per year in 2023
  - The Gulf Coast Ammonia plant in Texas City (2024), single-train ammonia synthesis loop with a capacity of 1.3 million tons per year
  - Proman’s Gas y Petroquimica de Occidente’s 732,000 ton per year ammonia plant in Mexico is delayed, start-up expect in 2026
  - OCI Clean Ammonia project in Beaumont Texas, single train blue ammonia synthesis loop with a capacity of 1.1 million tons per year. Start-up in 2025
- Ammonia capacity in Canada has stayed relatively flat in the recent years, at about 5.4 million tons

Over the past few years, ammonia has been categorised based on the type of feedstock used for its production and carbon intensity – this has been used to visualise its environmental impact

Ammonia Pathways



Commercial synthetic ammonia production started in 1913 with a 30 tons per day plant using the Haber-Bosch process. Today, a commercial ammonia plant has a typical capacity between 1 000 to 2 200 tons per day, with some plants as high as 3 300 tons per day

- Most of the world's ammonia output is manufactured by combining hydrogen and nitrogen over a catalyst in an exothermic reaction
- Nitrogen is easily sourced directly from air, and in some processes via an air separation unit (ASU) where pure nitrogen is required. The source of hydrogen, however, is more complex and requires energy intensive processes

Ammonia produced commercially is virtually entirely brown/grey ammonia where hydrogen is generated from a fossil fuel feedstock. In 2022, there were over 750 ammonia plants in operation with a combined capacity of 260 million tons per year

- Grey ammonia is produced from a natural gas feedstock where hydrogen is produced by steam methane reforming (SMR)
- Brown ammonia is produced from coal gasification to form a syngas.

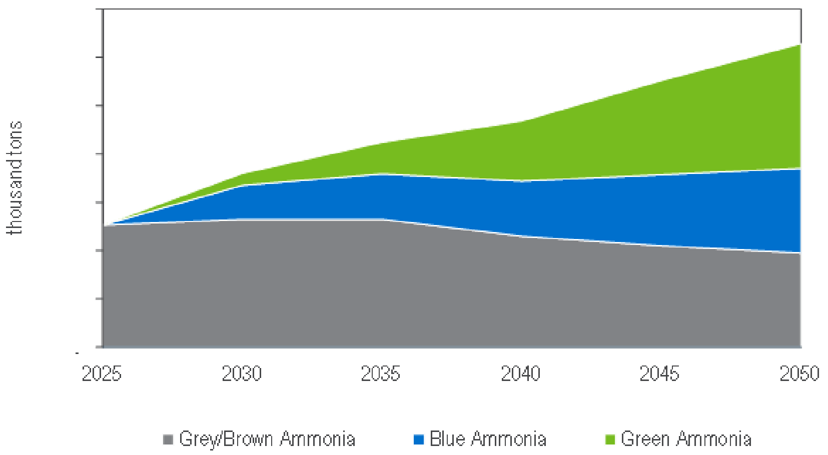
To reduce the carbon intensity of ammonia production two further pathways are being considered for commercial production

- Blue ammonia – grey ammonia with carbon capture and storage technology applied to the manufacturing process
- Green ammonia – hydrogen is produced via electrolysis of water using renewable energy

All pathways use Haber-Bosch technology and the ammonia produced is of the same specification

The United States and Canada are expected to invest into green and blue ammonia capacity in the second half of the decade to meet demand in the emerging low carbon energy market

North America Ammonia Capacity Split by Type, 2025 - 2050

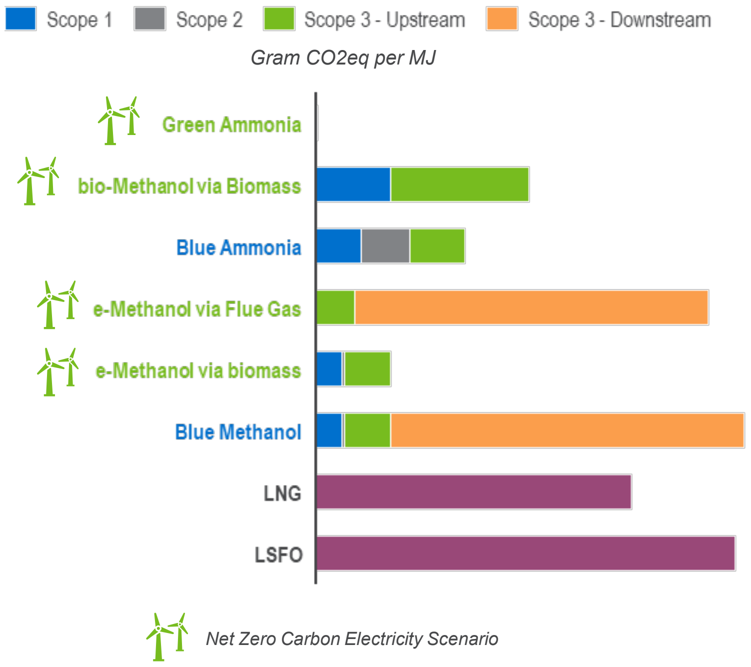


- Regional advantages
  - Existing ammonia infrastructure,
  - Relatively low price of natural gas
  - Existing experience in carbon capture and storage
  - Available and economical renewable power
- There have been blue ammonia capacity announcements in the United States and Canada. A few notable ones…
  - Linde's blue hydrogen project in Texas will supply the OCI Clean Ammonia project, largest of its kind when operational at 1.1 million tons per year
  - JERA and Uniper are also exploring options to produce blue ammonia in the US Gulf Coast as the collaboration aims to produce two million tons per year clean ammonia with potential to expand up to eight million tons per year
  - In Alberta, Itochu and Petronas have announced a joint project for the production of one million tons per year of blue ammonia
  - South Korea's E1 Corporation has also established partnership with Hydrogen Canada Corp for the import of one million tons of blue ammonia from Alberta, Canada

Carbon Intensity

Lower carbon ammonia is one of the clear leaders amongst marine fuels when analysed based on life cycle GHG emissions

Marine Fuel Life Cycle Intensity Estimate



Transport emissions assumed to be negligible

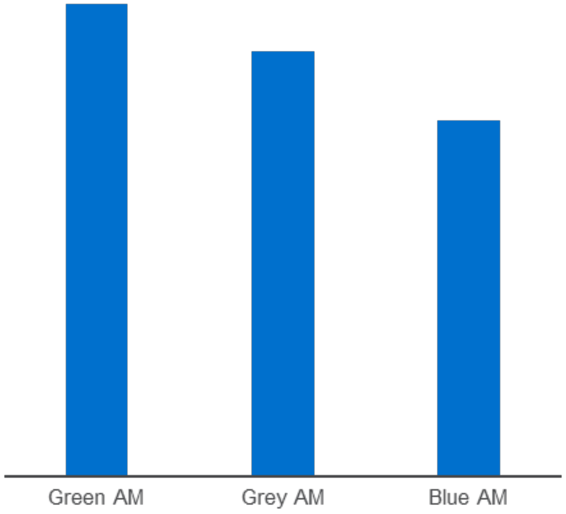
Combustion is the major contributor of overall emissions to the life cycle analysis. This study has assumed that technology can be developed to avoid significant nitrous oxide emissions when ammonia is combusted. If this is possible, lower carbon ammonia could be a GHG emission free fuel

- Energy density of potential marine fuels is a key consideration when comparing carbon intensity
- The feedstock and utility assumptions are a key consideration when completing carbon intensity analysis
- Blue ammonia results in a reduction in carbon intensity of around 50 percent compared to LNG
- Blue ammonia carbon intensity is heavily dependent of the efficiency of the carbon capture system. A less efficient system than assumed in the study and limited nitrous oxide emissions could result in blue ammonia carbon intensity being comparable to LNG

Cost Competitiveness

Blue ammonia is competitive with grey ammonia, natural gas price and electricity are key drivers

Ammonia Cost of Production
(Location: Western Europe, Year: 2023)



Source: NexantECA

The renewable energy cost is the largest cash cost component of green ammonia production. Green ammonia cost of production is therefore heavily dependent on the renewable electricity price

- Over 90 percent of electricity consumed in an integrated green ammonia plant is by the electrolysis of water to produce hydrogen
- Countries and regions with access to low-cost renewable energy, may have a significant cost advantage compared to those with limited potential for renewable energy generation
- Green CAPEX is higher and not reflected on the graph

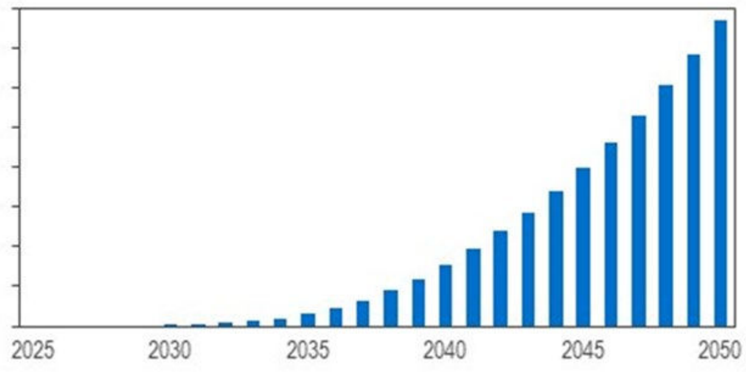
Grey and blue ammonia are significantly impacted by natural gas prices. Natural gas is 80+ percent of the cash cost for blue and for grey

Market Outlook

Various low carbon marine fuels are under development. It would appear a mixture will be required to meet the IMO's targeted reduction in carbon intensity

Forecast low carbon Ammonia as Marine Fuel

(Million tons of fuel oil equivalent)

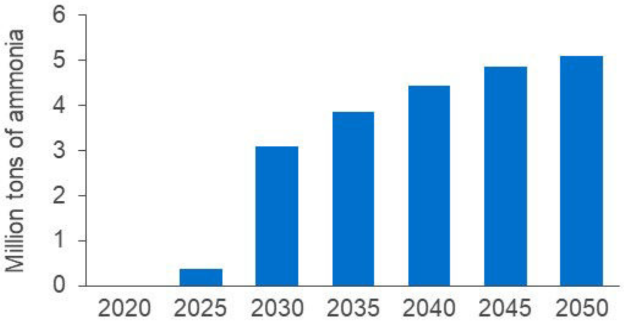


IMO has targeted reduction in carbon intensity of at least 40 percent by 2030 and reduction in GHG emissions by 50 percent in 2050

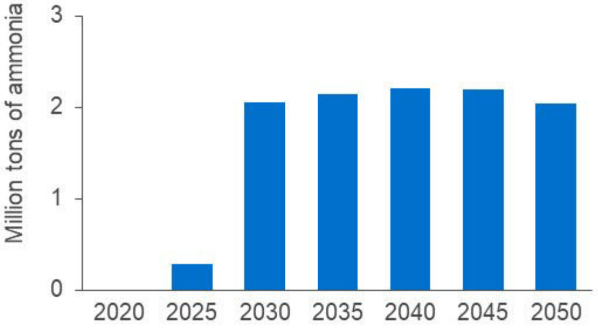
- The near term target can be achieved with switch to LNG, more efficient vessels and operational optimisation therefore we do not expect to see the penetration of low carbon fuels in the short term
- Low carbon marine fuels are expected to start entering commercial fleets after 2025. While various zero carbon fuels are in development it is difficult to predict which technology will be the most successful
- NexantECA expects the technical challenges associated with the use of ammonia as a marine fuel to be overcome in the next decade; we foresee ammonia accounting for over 60 percent of the energy demand for low/zero carbon fuels

Japan and South Korea have included the co-firing of ammonia in coal-fired power plants in their respective New Green Growth Strategy

Forecast Ammonia Demand due to co-firing in Japan



Forecast Ammonia Demand due to co-firing in Korea



Japan and South Korea envision the use of ammonia as a fuel source for energy generation due to high cost renewable power and limited interconnections for renewable power sharing

- Under the proposal, both Japan and Korea have set targets for co-firing of ammonia of 20 percent by 2030, increasing to 50 percent by 2050
- The combined ammonia demand due to co-firing in coal powered power plants in 2030 could range from five million tons to 34 million tons if government target are achieved. The low case is shown on the right

Market Opportunities - Methanol

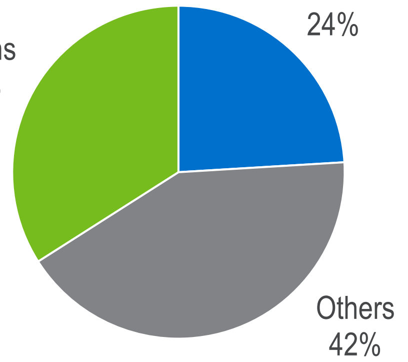
The methanol industry has transformed itself over the last 15 years with the growth in olefin and fuel applications driving global demand

Methanol is the simplest of the alcohols with a chemical formula of CH_3OH and it is used either as a feedstock for chemicals or fuel derivatives

- Historically chemical derivatives (acetic acid, formaldehyde, and others) accounted for almost all methanol demand
- New markets emerged in fuels and olefins
  - Fuel (e.g., MTBE, gasoline blending, biodiesel, and DME) now occupies a quarter of total global methanol demand
  - Olefins is the fastest growing chemical end use and is now the largest single outlet for methanol
- Fuel and Olefin demand is concentrated in China
  - Coal based methanol-to-olefins (MTO) is located entirely in China
- Within fuel applications, the maritime market is seen as a key emerging sector of demand for ships to comply with stringent emissions regulations

Methanol Value Chain

2023, Approx. 122 million tons

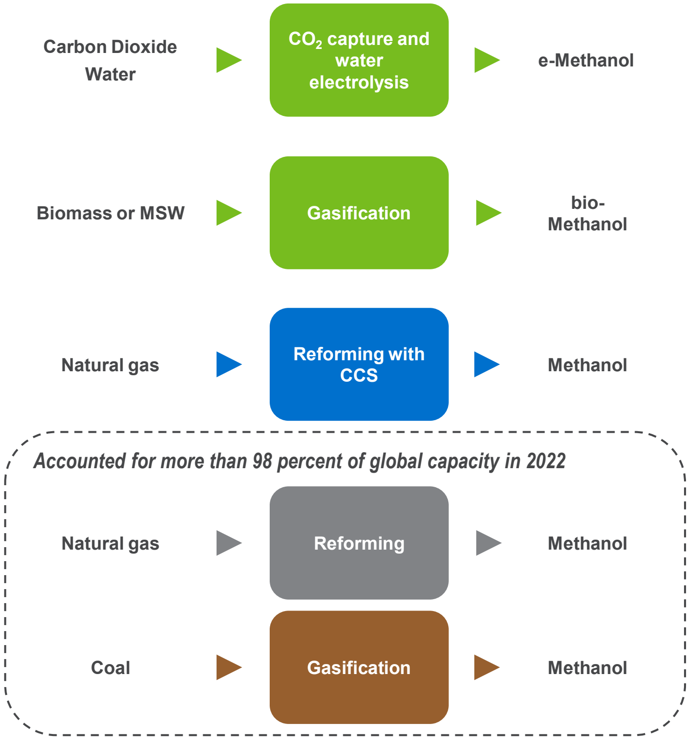


Chemical	Fuel
▪ Olefins ▪ Formaldehyde ▪ Acetic Acid ▪ MMA ▪ DMT ▪ Methylamines, Chloromethane, Solvents & Others	▪ Gasoline Blending ▪ MTBE ▪ DME ▪ Biodiesel

Source: NexantECA

Over the past few years, methanol has been categorised based on the type of technology used for its production – this has been used to visualise its environmental impact

Methanol Pathways



Green methanol assumes that the source of carbon in the methanol is 'renewable' and can be split further into two categories – e-Methanol and bio-methanol

- E-methanol - Production of methanol utilising carbon dioxide from storage or pipeline and hydrogen from the electrolysis of water. The carbon dioxide and hydrogen are then combined to produced methanol
- Bio-methanol - Derived from biomass or municipal solid waste feedstock. The feedstock is initially gasified to produce a syngas which is then converted into methanol via a methanol synthesis loop and purified via distillation

Blue methanol assumes that the methanol is produced via conventional means, but that carbon dioxide emitted in its production is captured and sequestered or used

- Conventional production of methanol utilising natural gas feedstock with a bolt on carbon capture and storage facility that captures CO_2 from the flue gas of the plant
- This is seen as the easiest retrofit for existing facilities but requires additional CAPEX and leads to higher operating expenditure
- CCS infrastructure exists in Canada and more is under development in North America

Grey and brown colours are used to refer to conventional technologies based on natural gas or coal feedstocks respectively

Recent methanol capacity increases are grey, blue projects are under development

North American methanol capacity was 10.5 million tons in 2023. A few notable grey and blue projects…

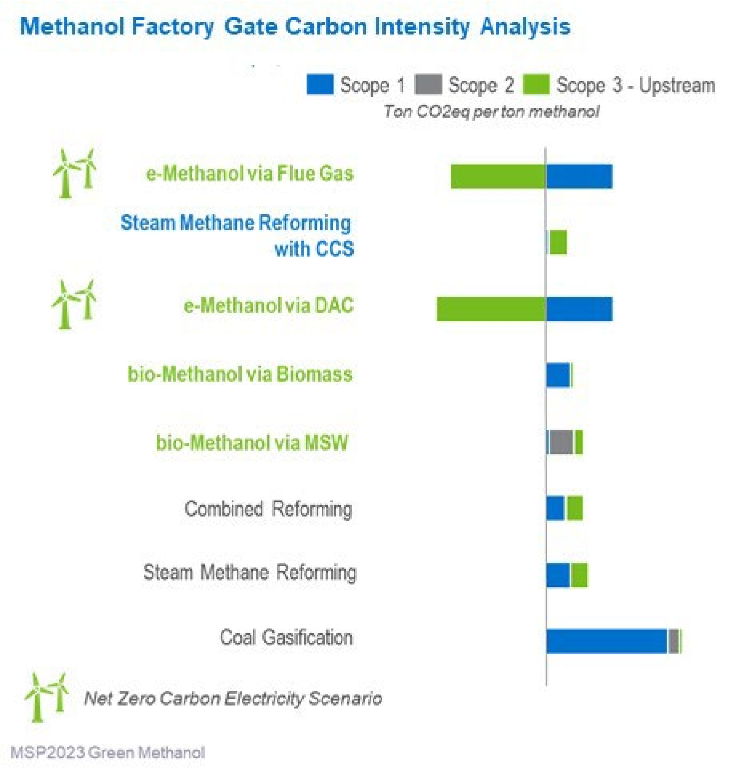
- Methanex Geismar 3 unit with a capacity of 1.8 million tons per year, expected to be operational this year
- Celanese / Mitsui JV expansion at Clear Lake TX to 1.62 million tons per year, project utilizes recycled CO2
- Proman G2X 1.4 million ton per year methanol project in Lake Charles LA, construction was halted earlier this year

Blue projects under development

- IGP Methanol in Louisiana first train of 1.8 million tons per year will have CCS
- Itochu and Petronas are studying blue methanol in Alberta as part of the blue ammonia study
- Nauticol 3.4 million ton per year blue methanol project in Alberta was cancelled in 2023

Carbon Intensity

Climate change and policy development are driving interest in lower carbon methanol



Blue methanol is a good first step solution, which can reduce the carbon intensity of existing methanol plants, however long-term it is likely that policy with favor green methanol

- Increasing pressure on conventional processes is likely to increase investment in all alternative methanol routes
- Blue methanol has the advantage of easier integration with current routes
- In the US, the IRA is heavily subsidizing CCS projects, which include the production of blue methanol through investments in regional hubs
- Carbon tax and ETS schemes in the US, Mexico and Canada will favor blue-methanol due to low carbon intensities. This is a potentially medium-term solution as more legislation about the use of carbon neutral methanol comes into effect

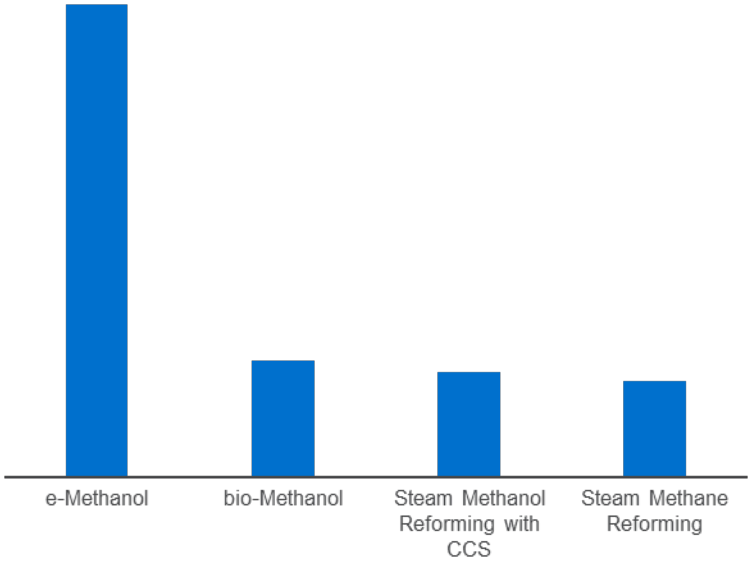
e-Methanol is among the least carbon intensive routes for production of methanol

- e-Methanol offers significant emission reductions vs conventional methanol routes
- The position of e-Methanol relies on the use of net zero electricity

Cost Competitiveness

Blue methanol and bio methanol are currently the most competitive versus grey methanol

Methanol Cash Cost Competitiveness Analysis



Source: NexantECA

e-Methanol is too high to compete with existing methanol facilities on the merchant market

- Electricity has a key impact on the position for e-methanol in comparison to conventional routes
- e-Methanol is based on existing facilities, scale up will help reduce cost

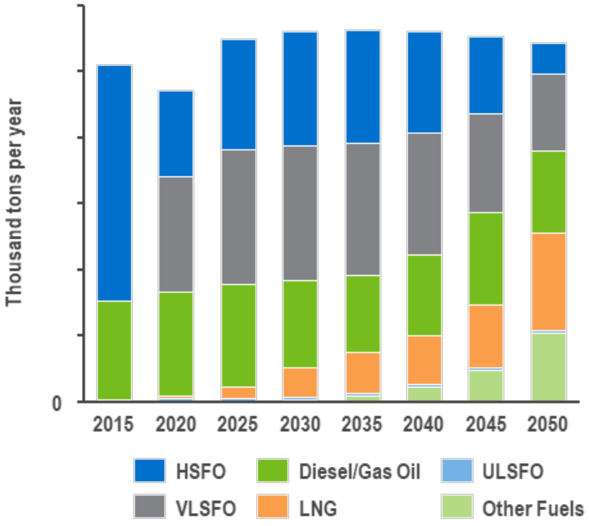
Bio-Methanol and blue methanol are the most competitive versus conventional SMR (grey) methanol

Market Outlook

While marine fuel is seen as a major source of demand for lower carbon methanol, there are several other options for shipowners and the change in fuel is typically a slow process

Global Bunker Fuel Outlook

2015 – 2050



Source: NexantECA

Methanol as a fuel still emits carbon dioxide but can meet new standards for marine fuels in Emission Control Areas

The use of alternative marine fuels is expected to grow by almost 20 percent per year until 2050 with lower carbon methanol expected to make up a significant portion of this demand

Methanol-fueled ships, are compliant with the most stringent emissions regulations and reduce CO2 emissions by up to 15 percent when compared to conventional marine fuels

- Methanol as marine fuel is well-proven
  - Over next few years, the market expects to see more than 30+ methanol-powered vessels entering the market, over 300 are on order
  - Supply infrastructure is also already in place for methanol, as it is shipped through many ports around the world

The alternative fuels landscape is scattered, and shipowners are hesitant to move into new fuels that are not yet used widely, mindful of risks of limited availability, high cost and trading limitations

- Methanol has the advantages in already being widely traded and handled as well as being used as fuel in other sectors. The target marine fuel market, however, is expected to adopt traditional methanol first then shift towards green methanol

Key Takeaways

Key Take Aways

Ammonia

- The need to decrease carbon intensity in current ammonia applications is driving strong interest in green / blue ammonia
- Emerging end uses and introduction of green / blue ammonia will significantly change the ammonia landscape over the next 25 years
- Blue ammonia will be the fastest growing in the near to medium term. Green ammonia will be limited to applications that can accept the cost premium

Methanol

- The improved environmental impact of lower carbon methanol and policy targeting climate change are driving interest in its adoption for fuel applications
- Blue methanol will be more competitive in the near to medium term.
- NexantECA expects that technical issues with e-methanol will be resolved over the long term

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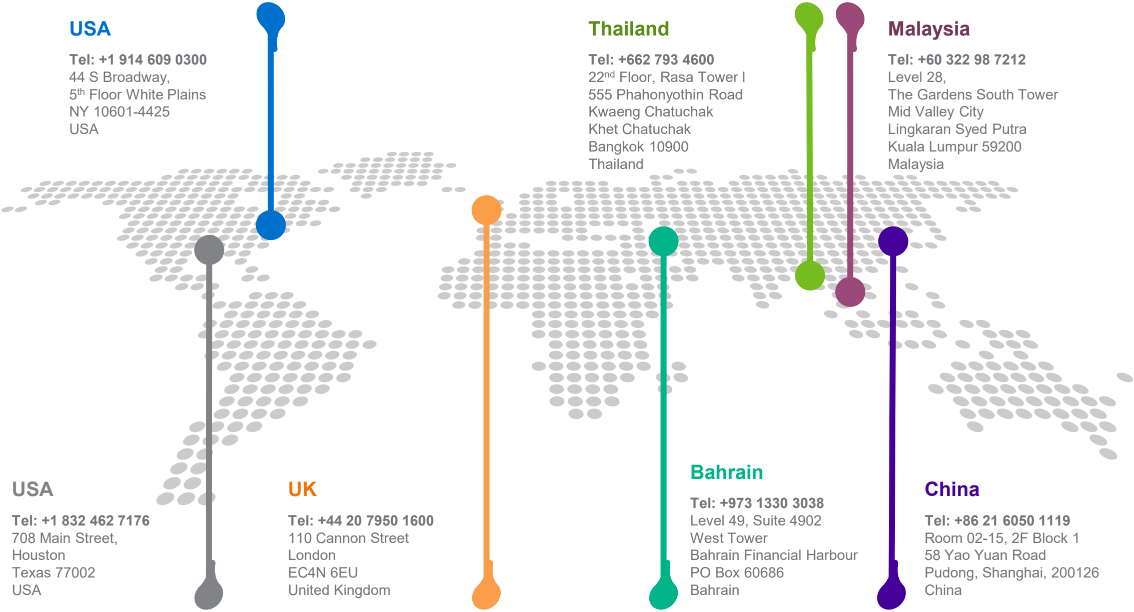

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