



Which Sustainable maritime fuels to deliver net-zero cruising?

29 November 2022

Welcome & Introduction

Marie-Caroline Laurent
Director-General CLIA in Europe



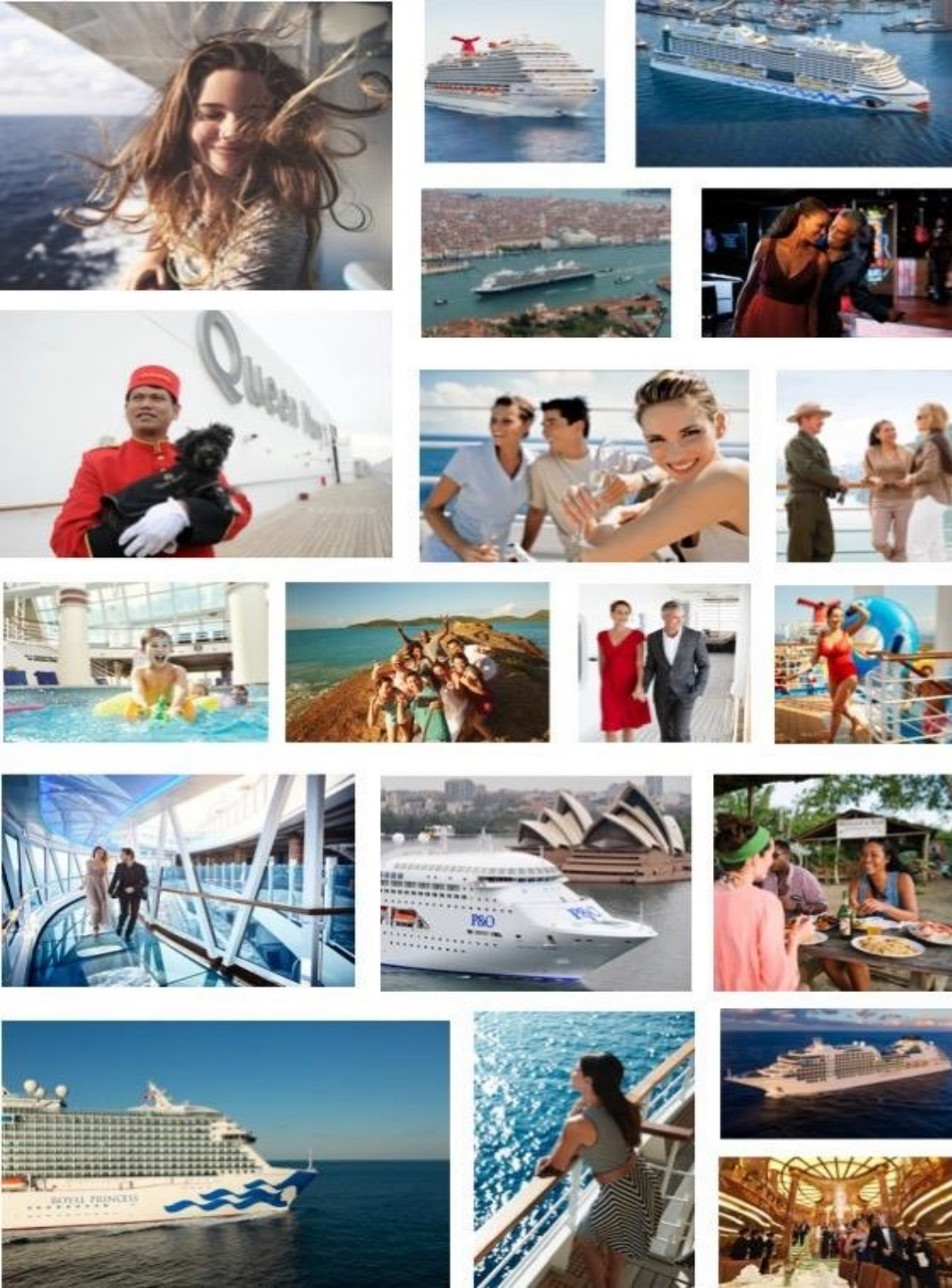
Future Fuel Options

Tom Strang

Chair, CLIA Sustainability Advisory Committee

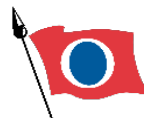
& Senior Vice-President, Maritime Affairs, Carnival Corporation & plc





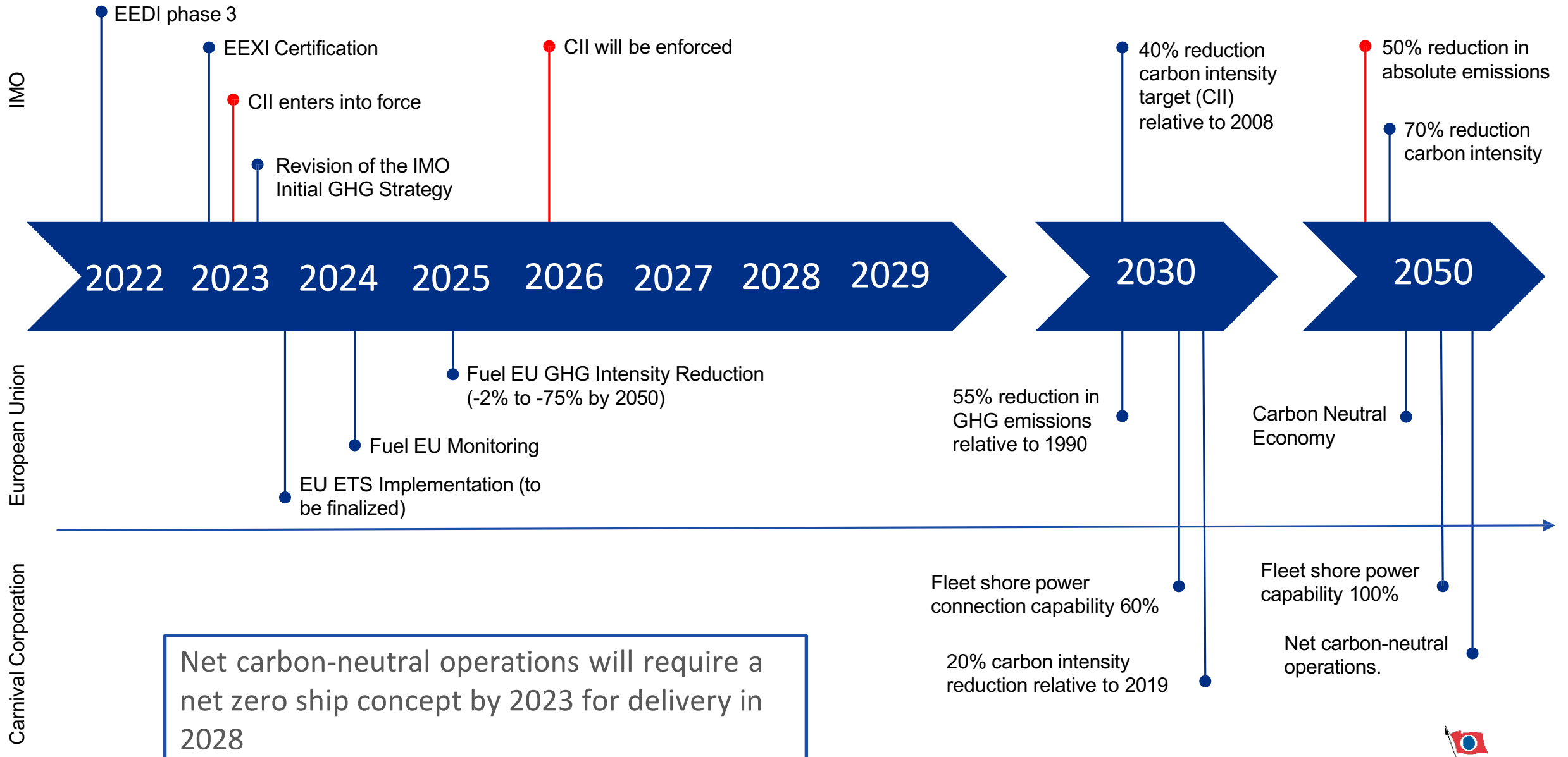
Future Fuel Options

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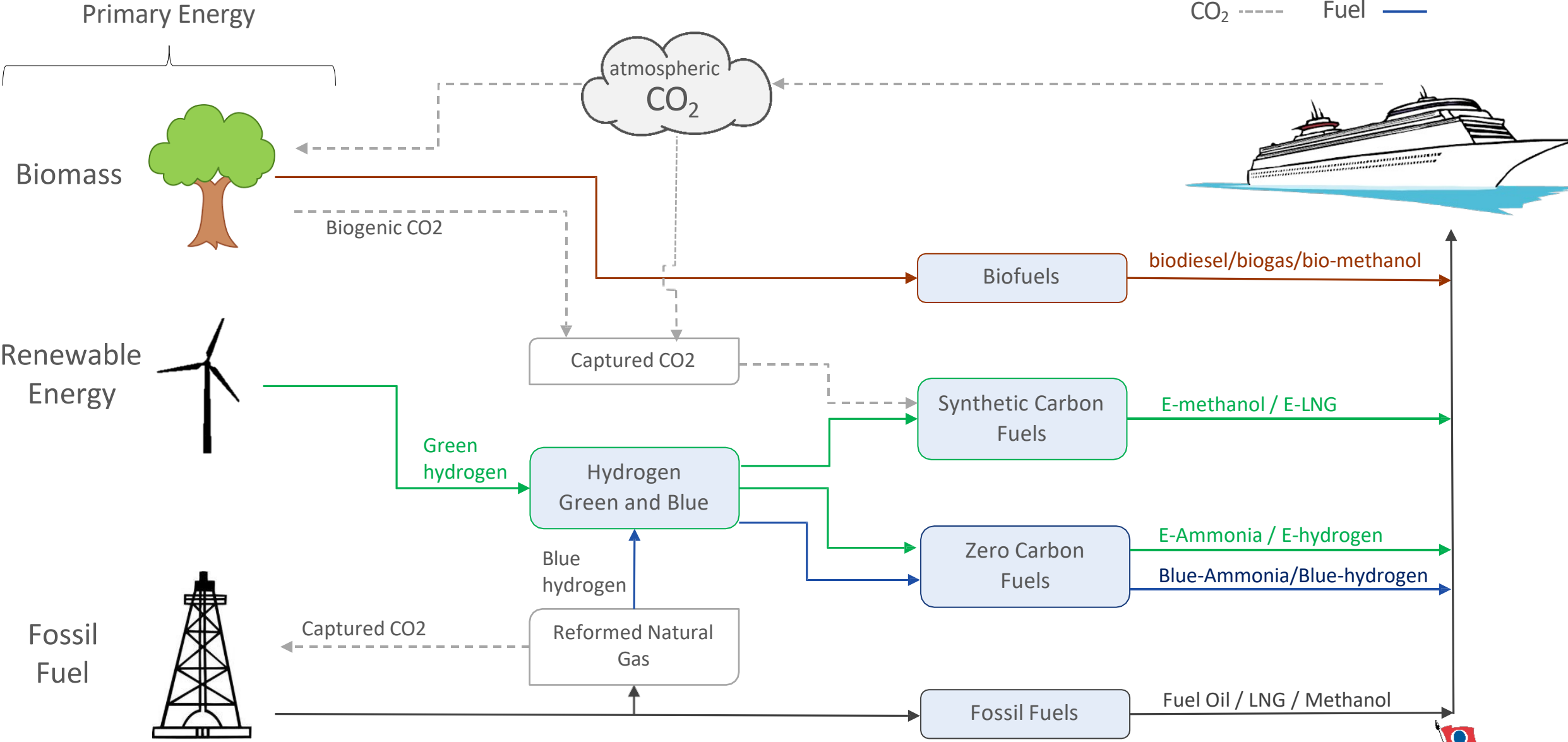


CARNIVAL
CORPORATION & PLC.

Carbon Regulation and Targets



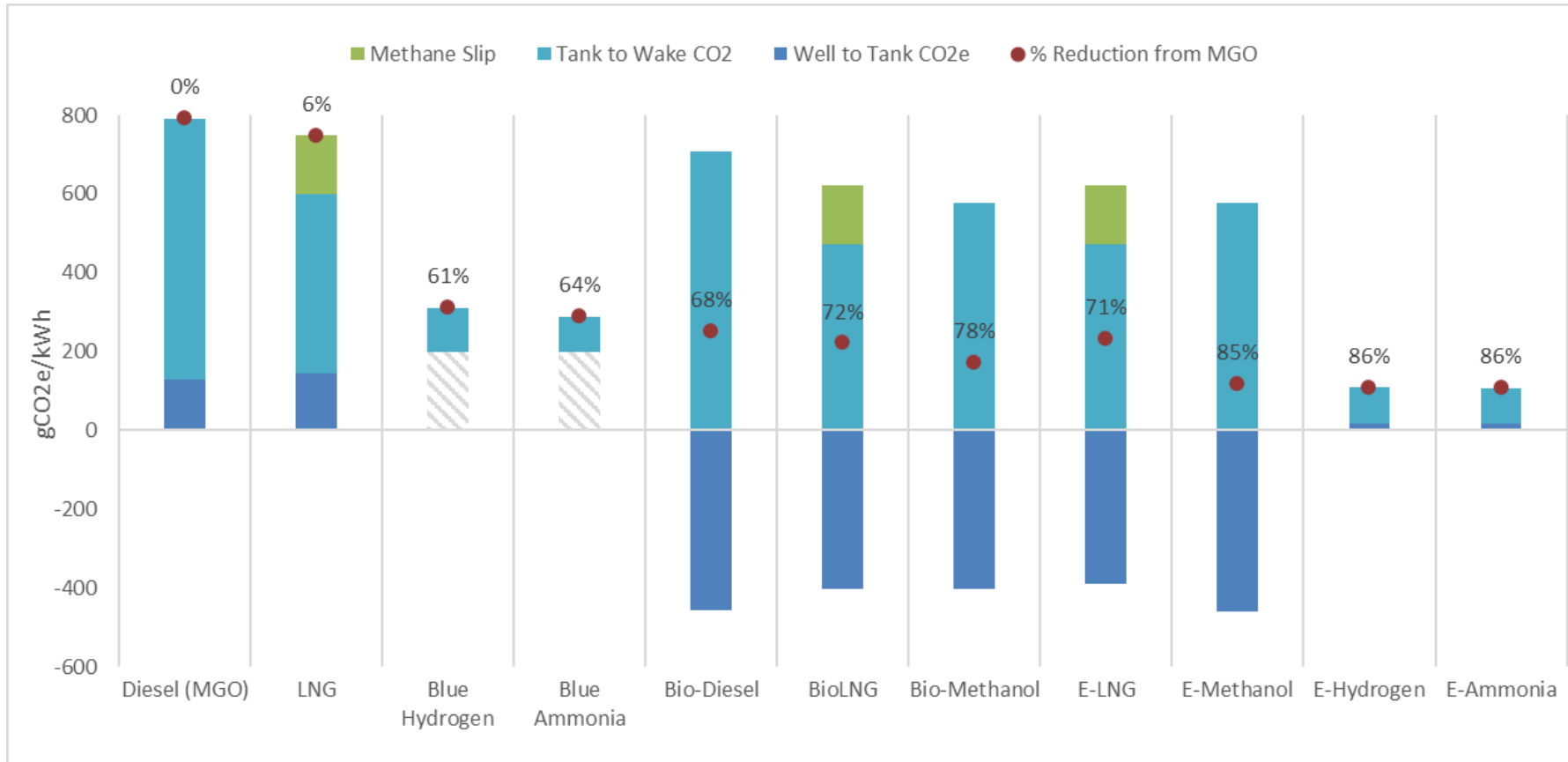
Fuels Energy Source and Production



Alternative Future Fuels – Lifecycle Emissions in 4-Stroke Combustion

- Well to Wake analysis of fuels is dependant on feedstocks and process to produce – published figures are notoriously uncertain
- Unlikely that any fuel option will be truly ‘Zero Emissions’
- Emissions are based on combustion in 4-stroke engine with a fossil MGO pilot fuel

- MGO/HFO/VLSFO provide baseline*
- E-fuels provide the largest GHG reduction*

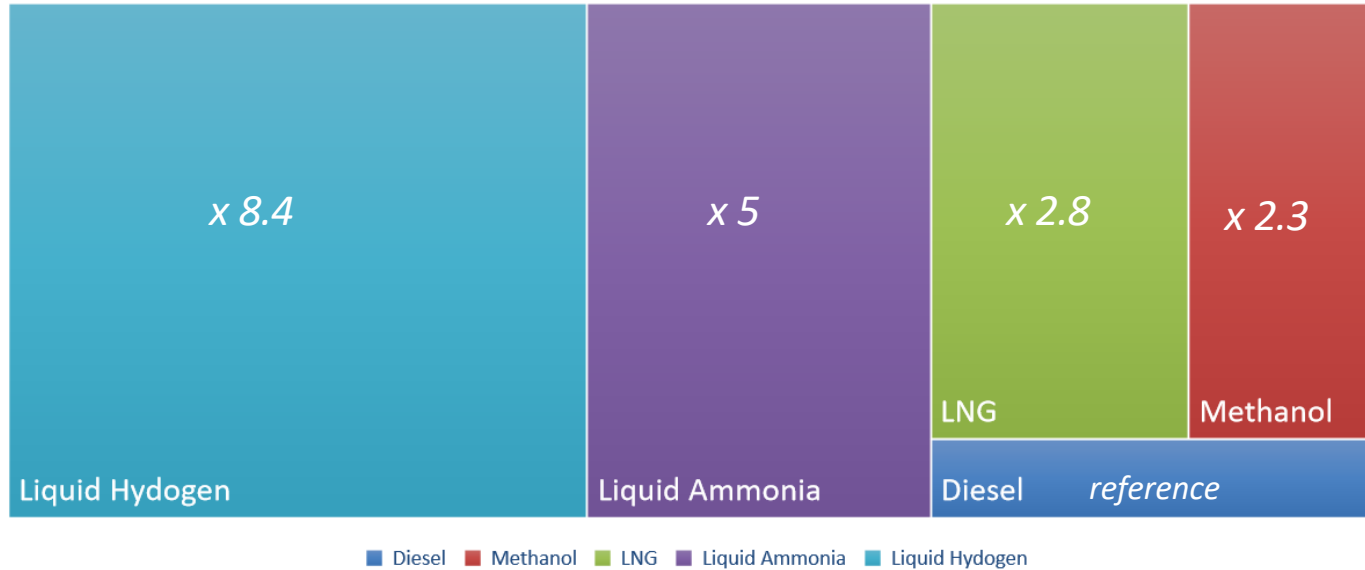


- Biofuels can provide substantial reductions*
- Blue fuels lifecycle emissions are uncertain*
- H2 and NH4 require pilot fuel and are not ‘zero emissions’*
- The politics are as important as the physics – zero ratings and multipliers incentivise uptake*
- Regulatory framework critical*

Lifecycle emissions of blue hydrogen and ammonia from natural gas with carbon capture (NG + CCS) is dependant on the carbon capture efficiency – currently unclear

Alternative Future Fuels – Onboard Storage

FUEL STORAGE VOLUME REQUIRED



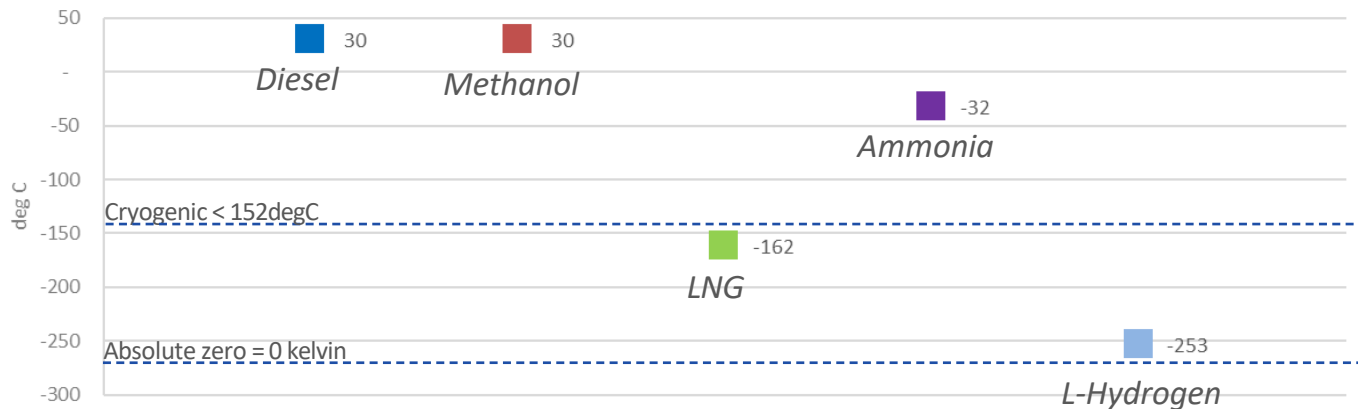
Required Fuel Storage

- Liquid hydrogen challenge for cruise vessels requiring global operation whilst meeting safe return to port regulation
- Methanol can be stored in conventional structural fuel tanks making it space efficient but requires internal cofferdams, nitrogen blanketing etc
- LNG best with insulated tanks capable of withstanding pressure build-up which are not space efficient

Storage Temperature

- Storage temperature provides an understanding of tank type, boil off rate and fuel handling characteristics
- Hydrogen requires cryogenic storage at temperatures of -253 deg C needing vacuum insulated tanks which makes storage and handling extremely challenging – volume constraints, rang etc

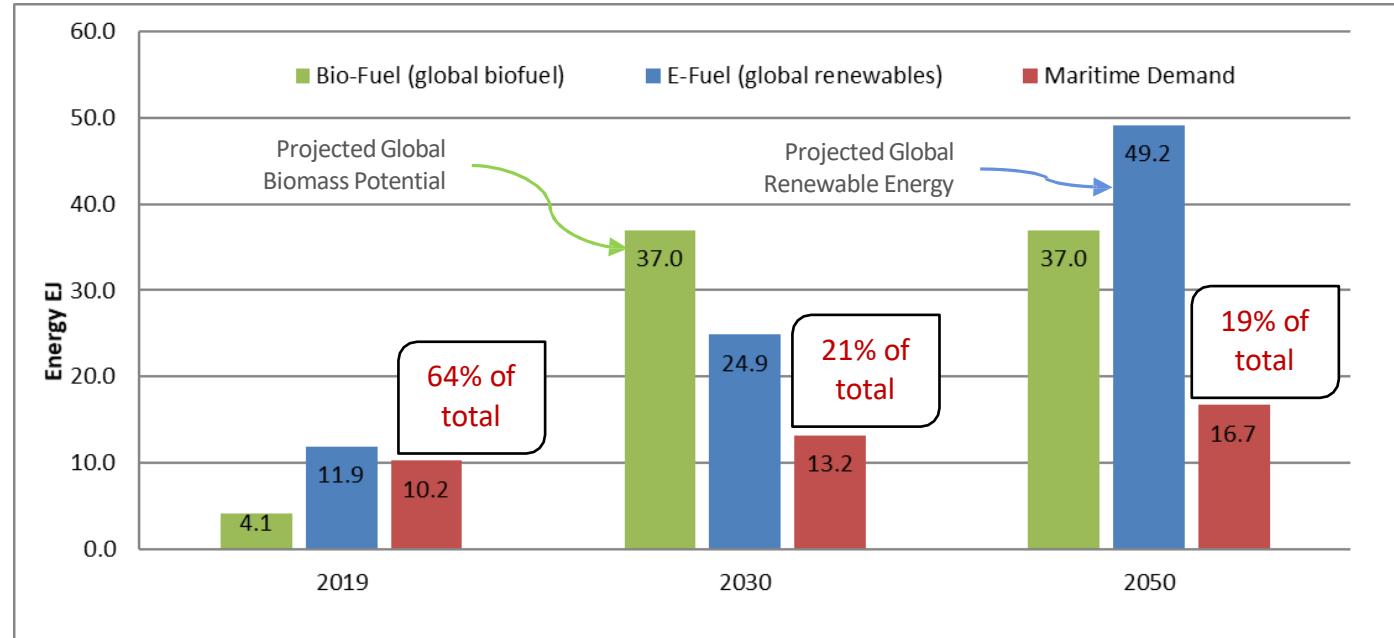
FUEL STORAGE TEMPERATURE



Alternative Future Fuels – Availability and Scalability

Based on availability of primary feedstock, the pathways will be: biofuels in near term moving to synthetic E-fuels in longer term.

What proportion of available resource would be available to shipping?



It is estimated that 2 EJ of biofuel may be available to shipping – 10% of demand.

2019

2030

2050

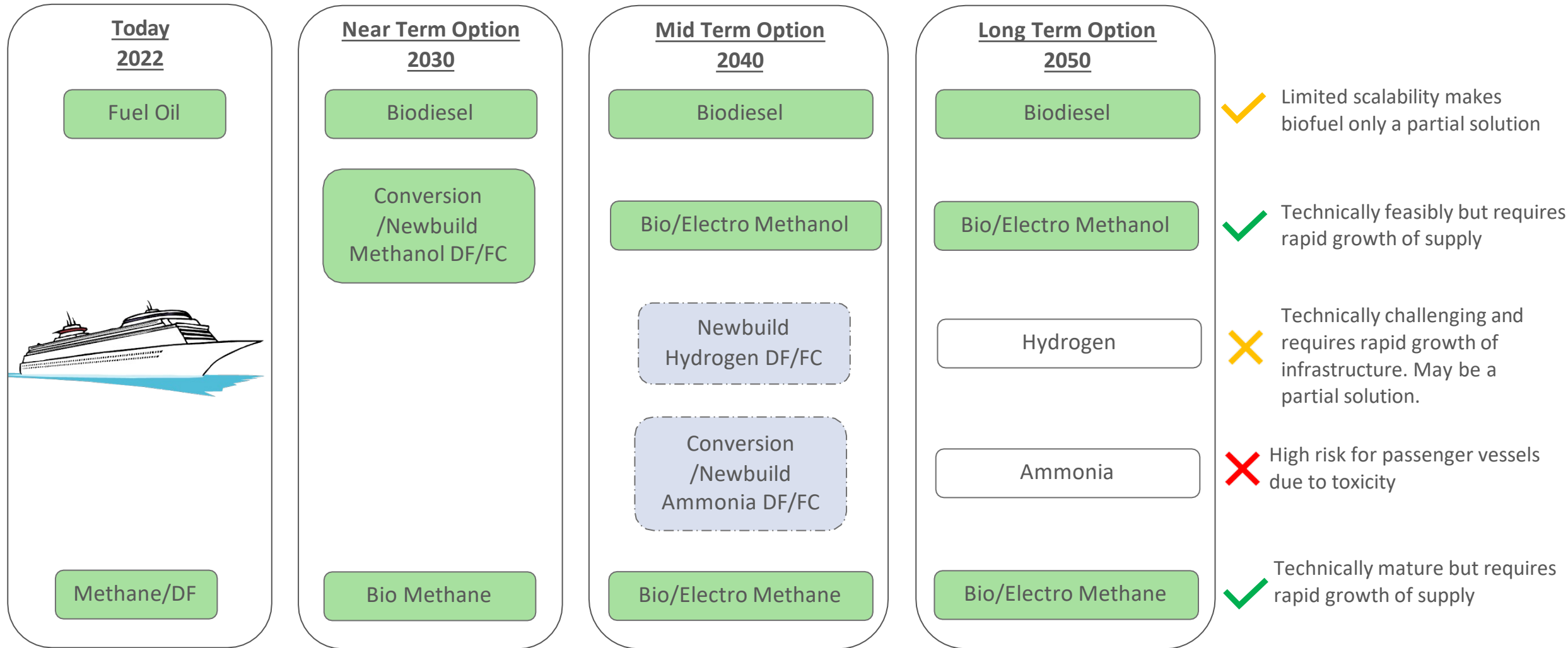
*Total maritime energy demand would outstrip global biofuel supply
 Maritime energy demand would consume all renewable energy using synthetic e-fuels*

*Biofuel has growth potential due to advances in production technologies.
 Electro fuel production will become reality but with limited availability*

*Biofuel growth is limited by available biomass resource.
 Renewables become more available making synthetic e-fuel production a reality.*

Future Fuel Pathways

Given the uncertainty on future fuel availability, designing for flexibility can be a long-term risk reduction strategy.

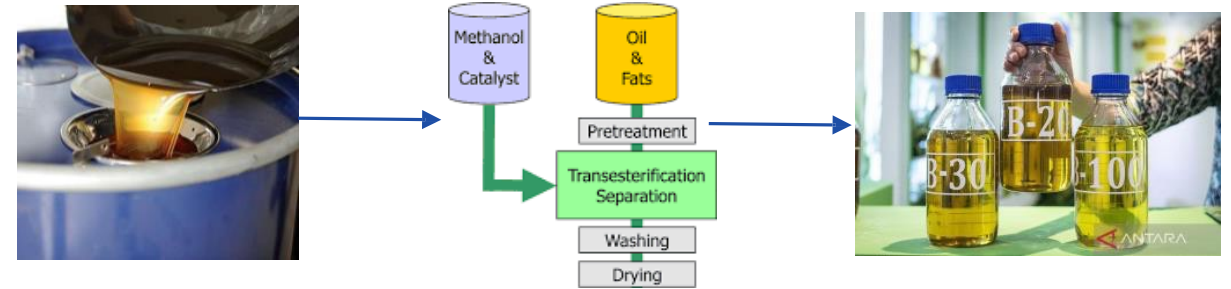


- DF = dual fuel engine FC = Fuel Cell
- Bio-fuels are available in the short term but likely not the most cost effective or widely available option in the long term.
- Electro fuels will become available in longer term with renewables development projects

Biodiesel and e-Diesel

Opportunity	Near term low carbon fuel, available today Proven drop-in fuels with no modifications Can be blended with existing fuels
Reward	~85% reduction in lifecycle CO2 emissions Developed regulatory framework
Risk	Scalability of supply and production capacity Competition with aviation/land transportation Not possible for fuel cell use

Goodfuels – B100 Advanced FAME



E-diesel also known as Fischer Tropsch diesel is omitted as an option due to a less efficient production process leading to significantly higher costs than other options.

Carnival Initiatives

Biofuel trials Netherlands – availability of biofuels and Government incentives make it an attractive option

- HAG and CMG completed biofuel trials (B30 and B100) delivering 23 to 78% reduction in lifecycle GHG emissions depending on blend
- In discussions regarding supply of bio residual fuel – more competitive, less competition from road and aviation

Biofuel Availability Study

- Completed a biofuel availability study with consultants examining near term global availability of biofuels
- In discussions with suppliers developing supply chains in Florida, Caribbean, Mediterranean and Australia

Bio-Methanol and e-Methanol

Opportunity

Regulation as a marine fuel exists
Suitable for retrofit and newbuild
Liquid at ambient temperature

Reward

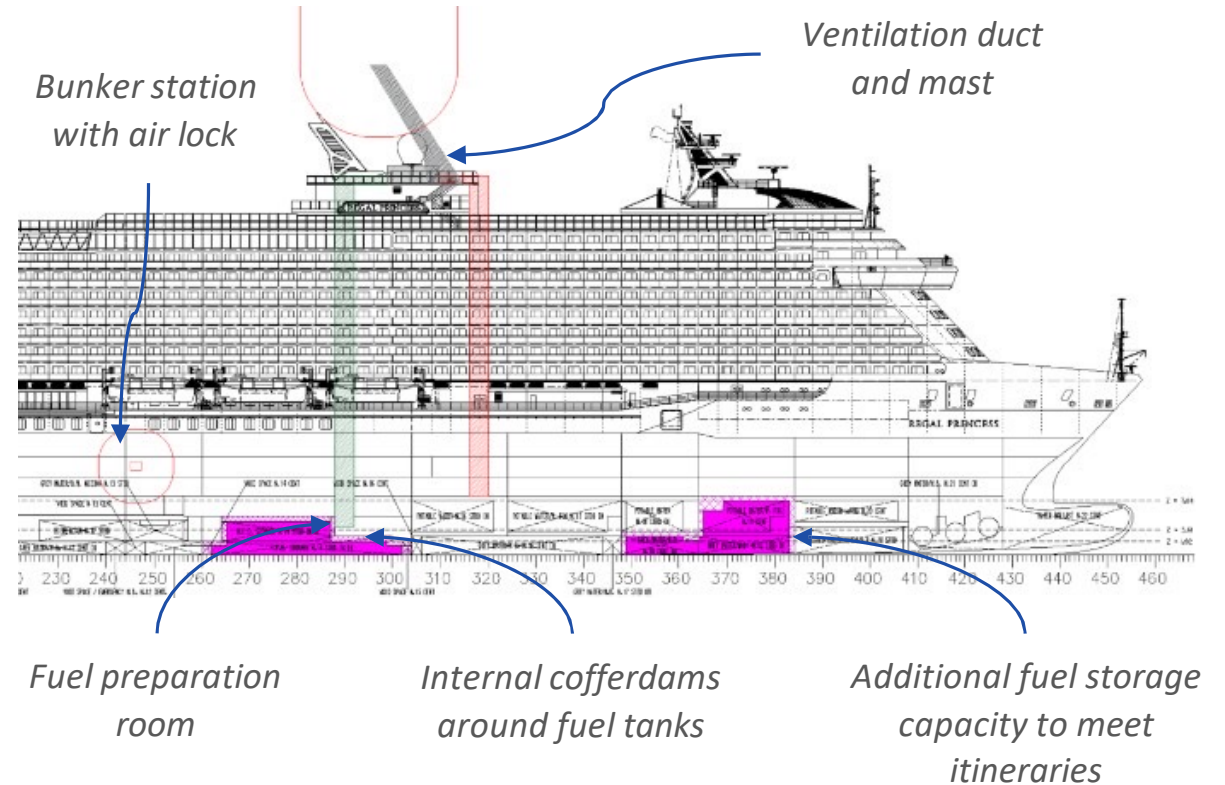
Up to 95% reduction in lifecycle CO2 emissions
Potential as both a bio and e-fuel

Risk

Currently minimal green production
Relatively high carbon content
High e-fuel production cost

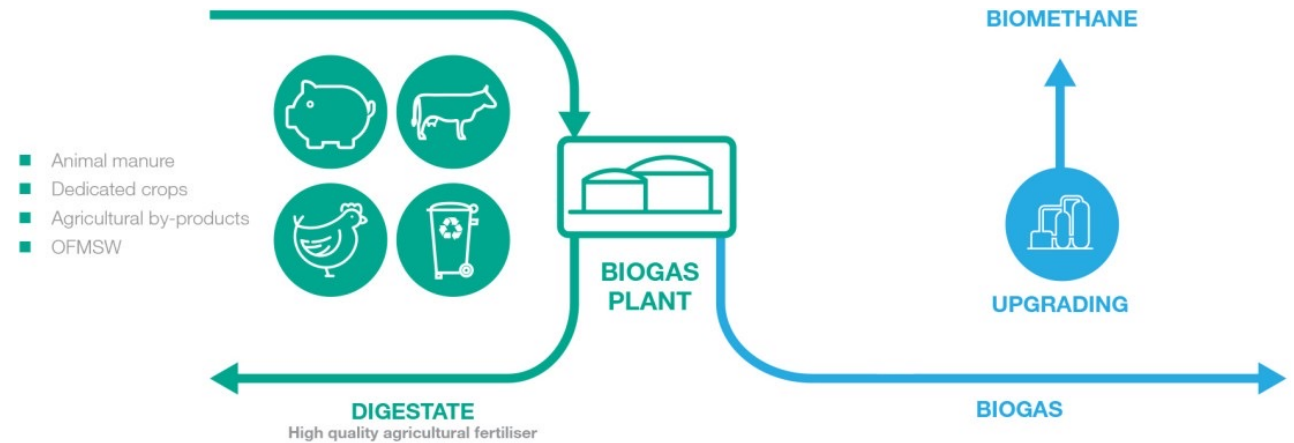
Carnival Initiatives

- Methanol retrofit feasibility studies quantifying the vessel impact and cost of retrofit, including ICE conversion and fuel cells as well as newbuild options
- Methanol Fuel Cell Trial - AIDAnova
- Methanol Supply - Investigating options to secure volumes of green and e-methanol



Bio-Methane and e-Methane

Opportunity	Biomethane is available today Proven drop-in fuel with no modifications Possibility to avoid physical delivery by mass balance
Reward	~85% reduction in lifecycle CO2 emissions Developed regulatory framework Can be blended with existing fuels
Risk	Scalability of supply and production capacity Methane slip reducing GHG reduction Logistics of supply



Carnival Initiatives

- Feasibility study ongoing for a biomethane trial with Shell using ISCC certified GHG reduction
- Supporting EU policy for biomethane use in shipping through a Guarantee of Origin scheme through EU Biogas Association
- Membership of Zero Methane Group established by LR to identify slip reduction pathways along with Shell and other vessel owners – in discussions to quantify and trial abatement
- Ecospray production systems for liquid bio methane with potential supply contacts for maritime

Future Perspectives

Ricardo Batista

European Commission DG MOVE



Carbon transformation for a climate positive world

Nicholas Flanders
Co-Founder & CEO, Twelve





—twelve

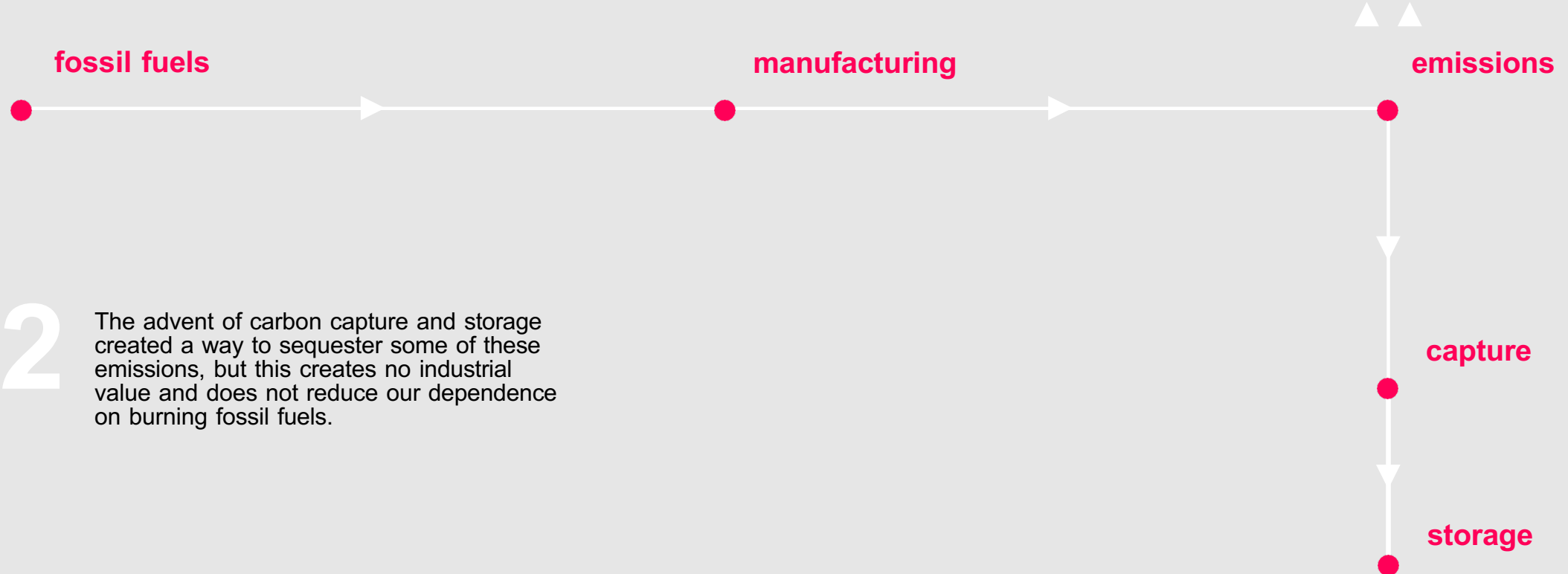
carbon transformation
for a climate positive world

from an extractive carbon economy...



1 Since the Industrial Revolution, we have emitted over 3 trillion tons of CO₂ into the atmosphere - much of which is directly from burning fossil fuels

to carbon capture and storage...



2

The advent of carbon capture and storage created a way to sequester some of these emissions, but this creates no industrial value and does not reduce our dependence on burning fossil fuels.

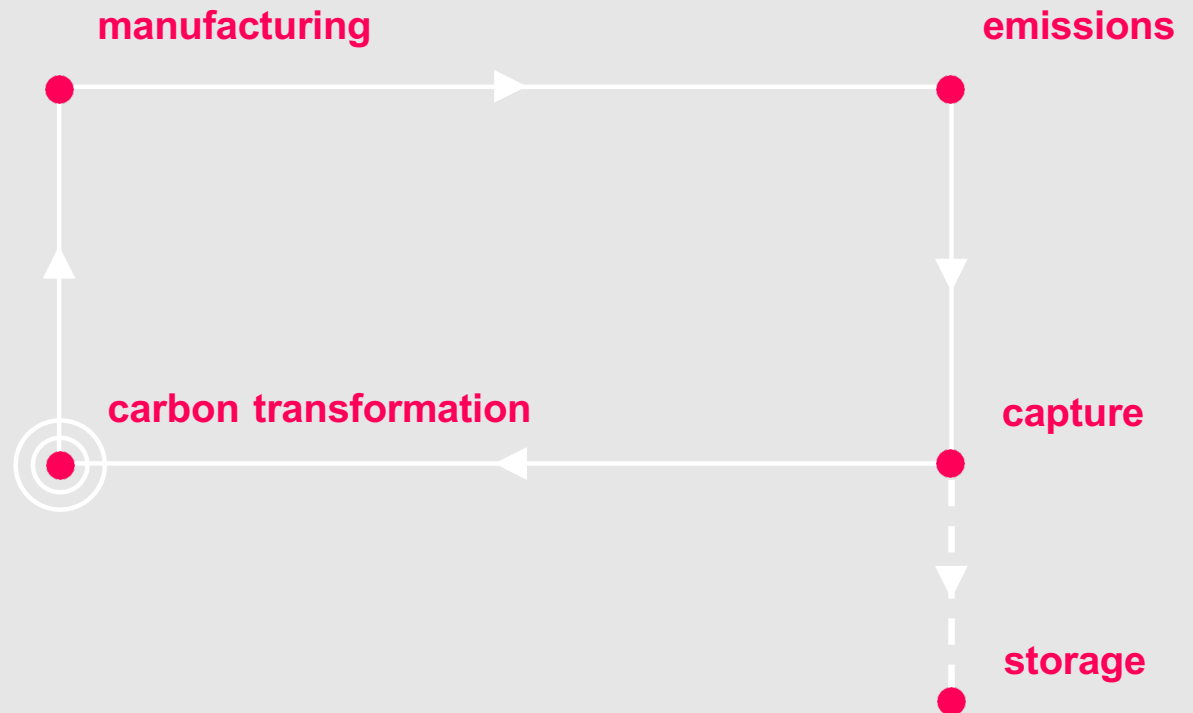
to zero emissions growth

fossil fuels

● X

3

Carbon transformation closes the carbon loop with zero emissions, requires no fossil fuels to grow manufacturing, and creates a source of revenue from what was once waste





transforming global CO₂ emissions



into a trillion-dollar opportunity



we have transformed CO₂ into products for flagship customers



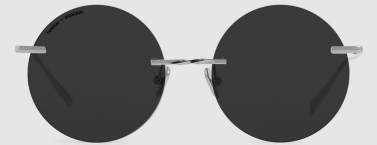
E-Jet®: world's first jet fuel made from CO₂ electrolysis



world's first CO₂Made® ingredients for Tide



world's first CO₂Made® auto parts





world's first CO₂Made® sunglass lenses



the element of change
is on the high seas




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 **PRESS RELEASE**

Virgin Voyages Announces Industry-First Partnerships with Trio of Sustainable Marine Fuel Providers

21 Sep 2022

e·marine[®]

by twelve

- Drop-in ready – can sail today
- >90% lower CO₂ footprint
- >50% reductions in particulate, >30% NO_x, and >90% lower SO_x
- 100% of the carbon in this fuel comes from CO₂
- Deliveries beginning in 2023, full scale in 2024

industrial photosynthesis

O12

Twelve's core technology: CO₂ electrolysis
CO₂ + water + electricity → products + oxygen

our investors and partners

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DC
VC

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 Microsoft

 Lawrence Livermore
National Laboratory

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 NREL

Lawrence Berkeley
National Laboratory

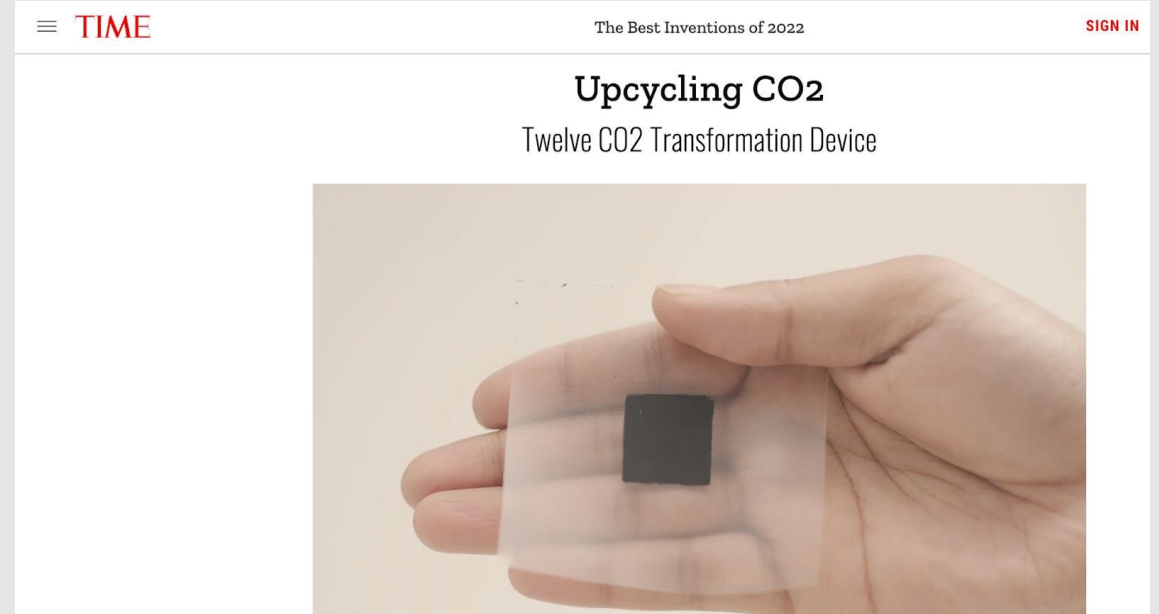
over \$200 million raised

Twelve is the world's #1 most innovative company in energy, 2022



Fast Company Most Innovative, 2022

1. Twelve
For Transforming CO₂ into petrochemicals, minus the fossil fuels



Time Best Inventions of 2022

the future is fossil free

Nicholas Flanders, Co-Founder | CEO

Nicholas@Twelve.co

Discussion

Thank you

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