Opportunities for Ports in the
Green Fuels Transition and Decarbonization Future

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Agenda

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2. Why e-Fuels?
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5. e-Fuels vs Bio-Fuels
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Introduction

This is COWI

Known for design of major **Marine Infrastructure,** Offshore Wind, Bridges & Tunnels

Approx. **7,000** employees worldwide

12 offices across North America

Global leaders in **Renewable Energy, Hydrogen, PtX and CCUS**

Net turnover: **1B USD**

90+ years of history

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Why e-Fuels?

Renewable Electricity
100 kWh

Battery Pathway

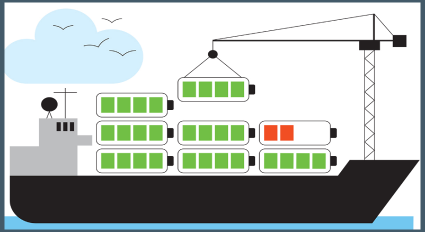
- Grid Transmission (90%) ➡ 90 kWh
- AC-DC Conversion & Battery Charging (85%) ➡ 77 kWh
- **Electric Vehicle** with Regenerative Braking **~70 kWh**

E-Fuels Pathway

- AC-DC Conversion (95%) ➡ 95 kWh
- Electrolysis Hydrogen Production (65%) ➡ 62 kWh
- **e-Fuels:** Diesel, Jet Fuel, Methanol, Ammonia **15-20 kWh**

Therefore, e-Fuels are focused on difficult to decarbonize applications

Batteries are too heavy for large & long-distance transport

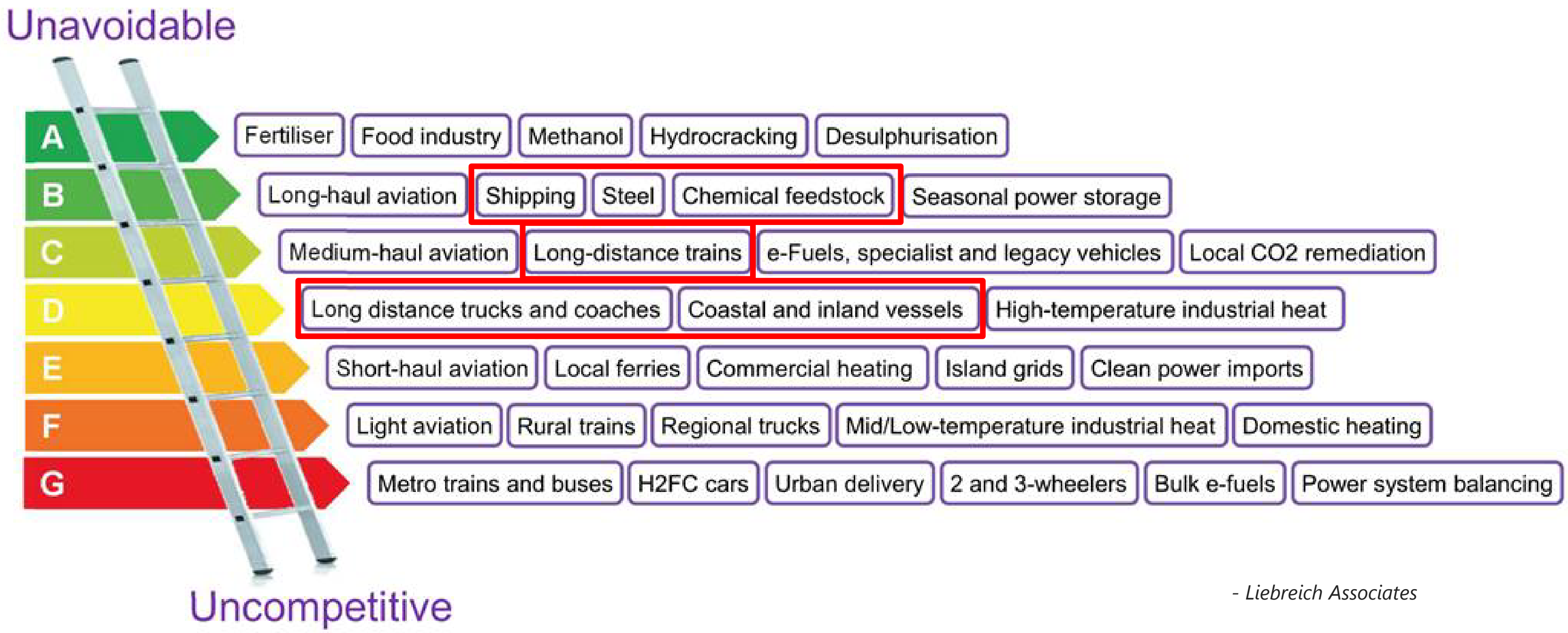


6,000 miles: 60 kt cargo, 55 kt battery
2,000 miles: 60 kt cargo, 17 kt battery

6,000 miles: 600 t cargo, 7,400 t battery
1,000 miles: 300 t cargo, 300 t battery

Requires Extreme Charging System!

E-Fuels Target Sectors



- Liebreich Associates

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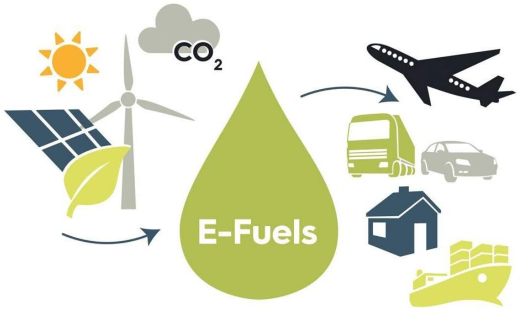
Hydrogen (& Derivatives) 101

Definitions

- **Power-to-X (PtX):** Transforming renewable electrons (electricity) to molecules
- **e-Hydrogen**: Main PtX product, produced from water electrolysis process
- **e-Fuels:** e-hydrogen from water electrolysis and all fuels derived from e-hydrogen, nitrogen from air (79% of air), and biogenic CO_2
- **e-Fuels Types:** conventional-like fuels like e-jet fuel and e-diesel, and unconventional fuels like e-hydrogen, e-methanol and e-ammonia
  - water + renewable electricity => **e-hydrogen**
  - e-hydrogen + biogenic CO_2 => **e-methanol / e-jet fuel / e-diesel**
  - e-hydrogen + nitrogen => e-ammonia
- **Biogenic CO_2:** Carbon dioxide from non-fossil and sustainable sources like air and biomass
- **Bio-Fuels:** Fuels derived from biomass and organic waste via chemical processing, examples of bio-fuels are bio-methanol, bio-methanol, biogas, bio-oil (marine biofuel) etc.



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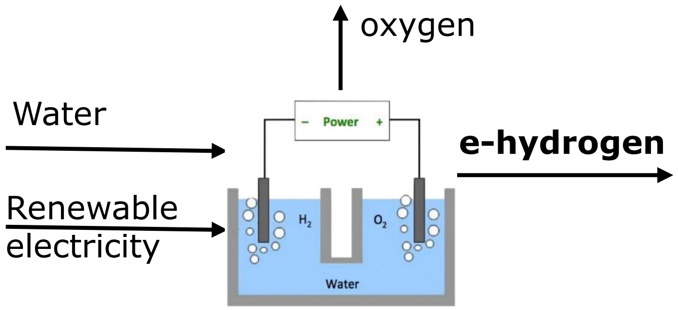
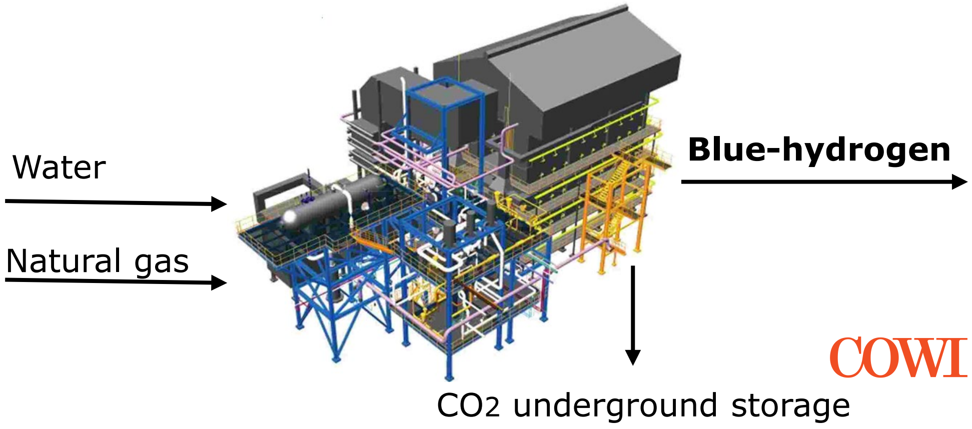
Green vs Blue Hydrogen

Green Hydrogen (e-Hydrogen) is produced through electrolysis, a process of splitting water into hydrogen and oxygen by electricity

Practical consumptions
~50 kWh electricity & ~15 kg water => 1 kg/h hydrogen

Blue Hydrogen (clean hydrogen) is produced through mainly steam methane reforming (SMR), a chemical process of splitting methane (natural gas) into hydrogen and carbon dioxide, followed by carbon capture and storage (CCS)





Hydrogen (& Derivatives) 101

Hydrogen Color Coding

BLUE
Gray or brown hydrogen where some or all of the CO_2 is sequestered or repurposed.

YELLOW
Hydrogen produced by electrolysis of water using grid electricity.

GREEN
Hydrogen produced by electrolysis of water using electricity from renewable resources.

WHITE
Hydrogen produced as a byproduct of industrial processes.

TURQUOISE
Hydrogen produced by the thermal splitting of methane (pyrolysis). Byproduct is solid carbon, not CO_2.

PINK
Hydrogen produced by electrolysis of water using electricity from nuclear Power.

GRAY
Hydrogen produced from natural gas through steam-methane reforming (SMR).

BROWN
Hydrogen extracted from fossil fuels, usually coal, using gasification.

CLEAN HYDROGEN is defined based on Carbon Intensity (CI) index, CI<2 kg CO_2 emission / kg H2

Examples of Hydrogen Applications in the US

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Power-to-X (PtX)

Hydrogen Gas Properties:

- Low density
- High gravimetric energy density 3 time of Diesel
- Low volumetric energy density - less than 10% of diesel @ 10,000 psi

The Challenge:

- Gas storage and transportation

The Solution:

- Conversion to liquid e-fuels
  - diesel, methanol, ammonia, liquid hydrogen

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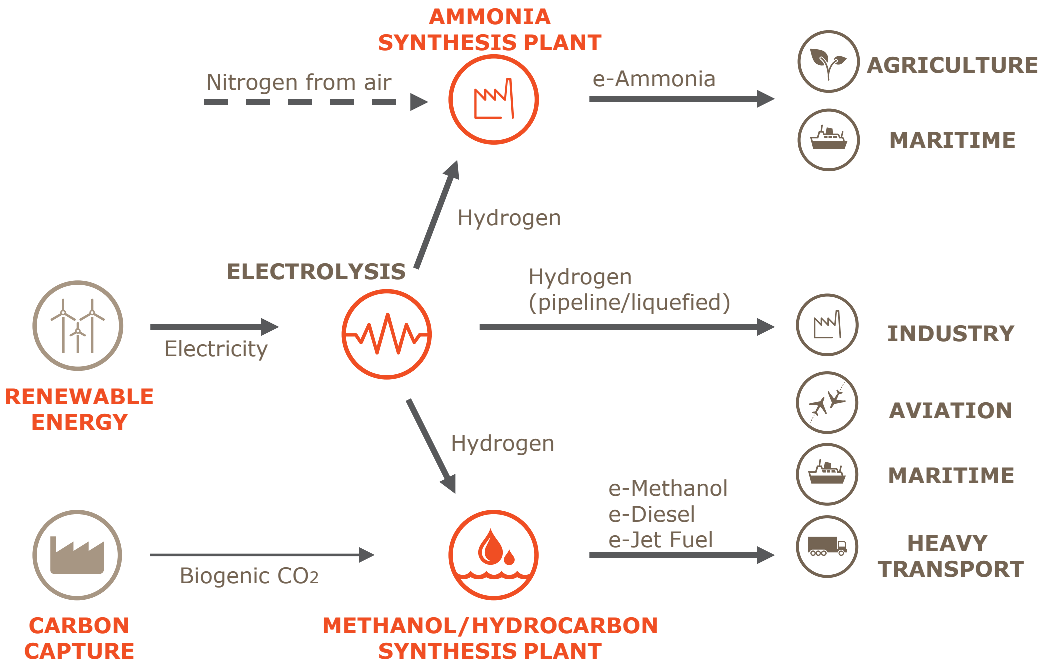
Power-to-X (PtX) Technologies

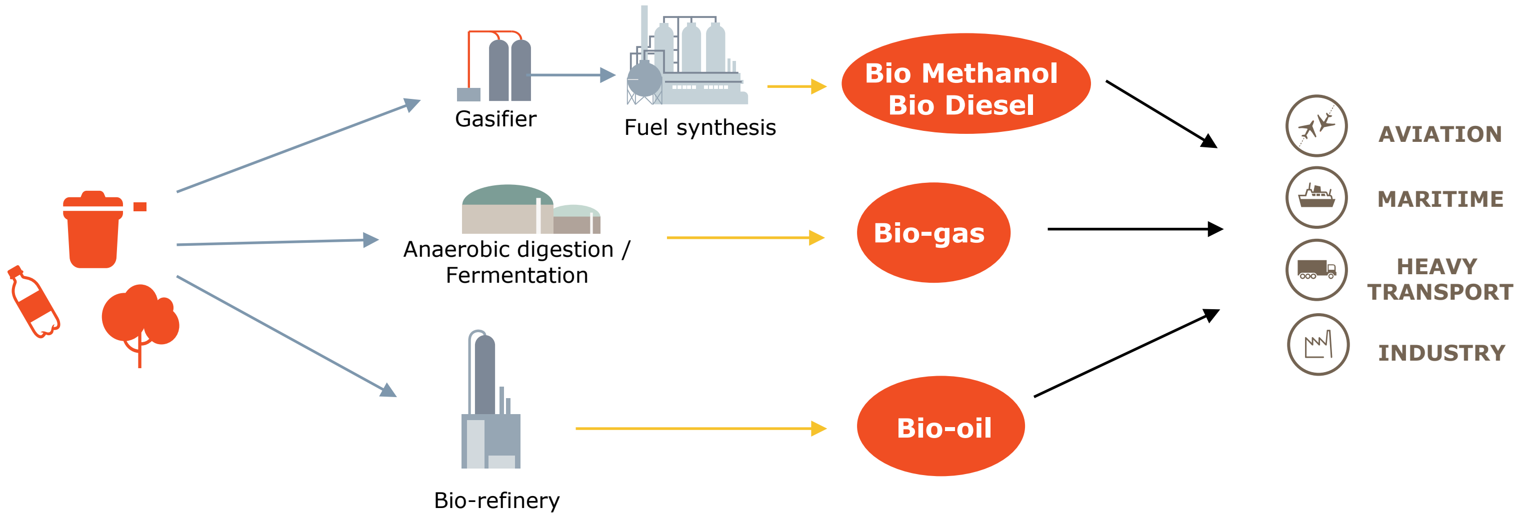
e-Fuels vs Bio-Fuels

E-Fuels vs Bio-Fuels

e-Fuel Production & Use



Bio-Fuel Production & Use



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Shipping Fuels of the Future

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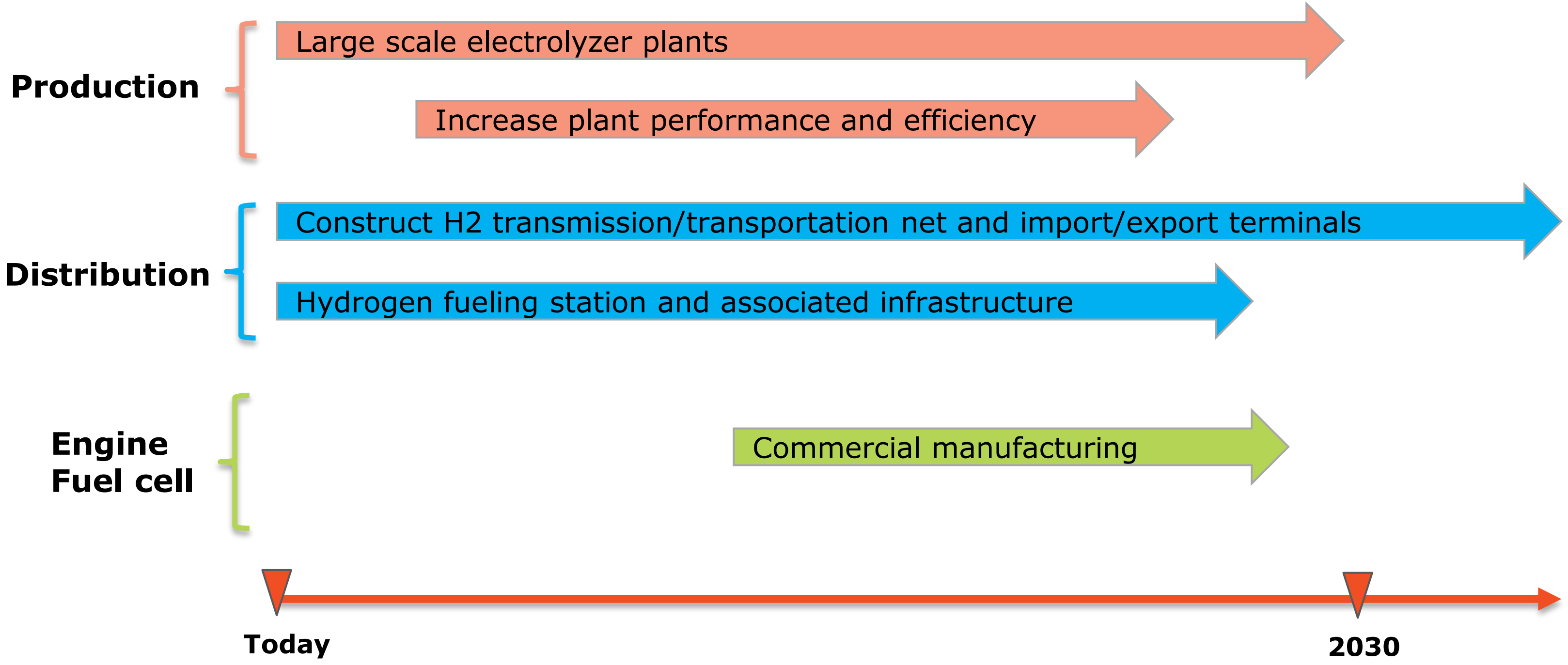
Current Status and Future of Shipping Fuels

- 99.9% of marine fuels are fossil based
- 940 megatons carbon emissions from marine fuels every year

- IMO targets 50% reduction in GHG emissions from international shipping by 2050 compared to 2008
- Total investment needed to decarbonize the shipping industry estimated around $2 trillion; 85% of which is needed for fuel production and infrastructure

e-Hydrogen Technology Status



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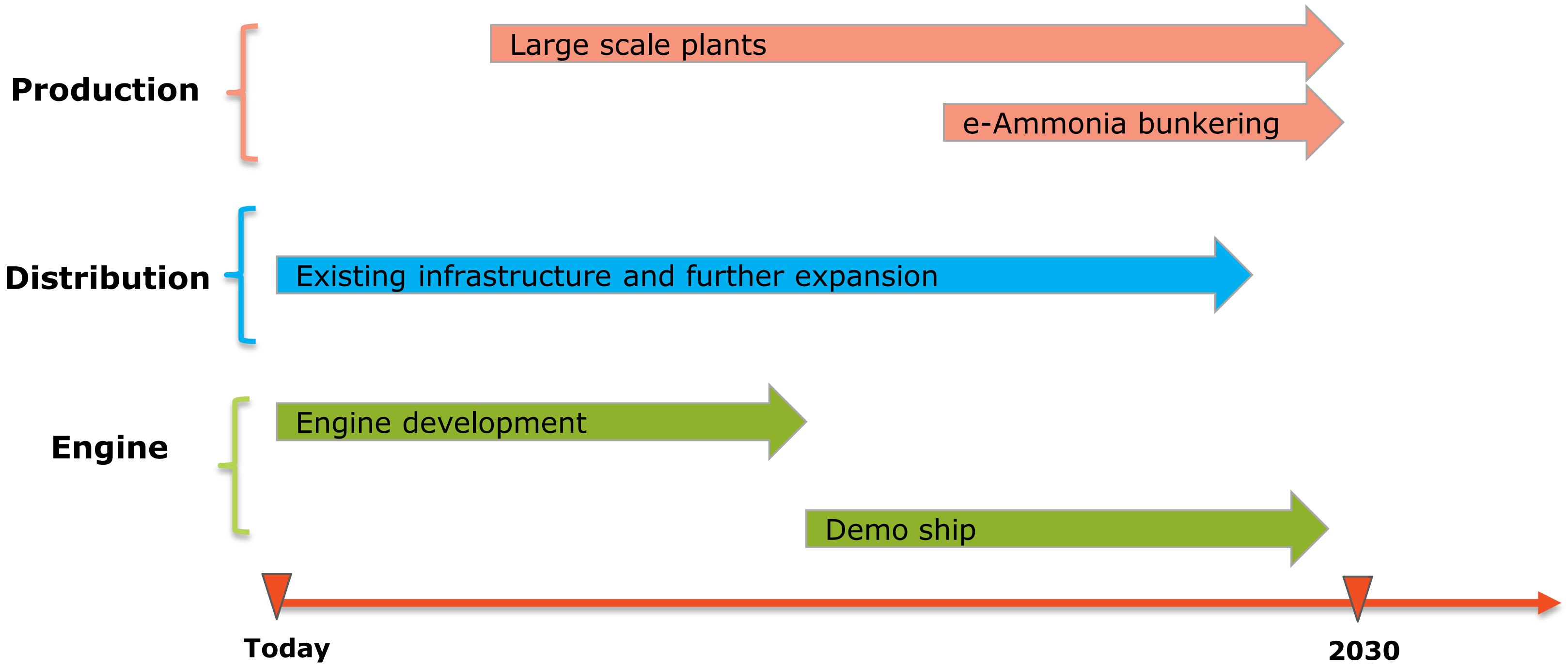
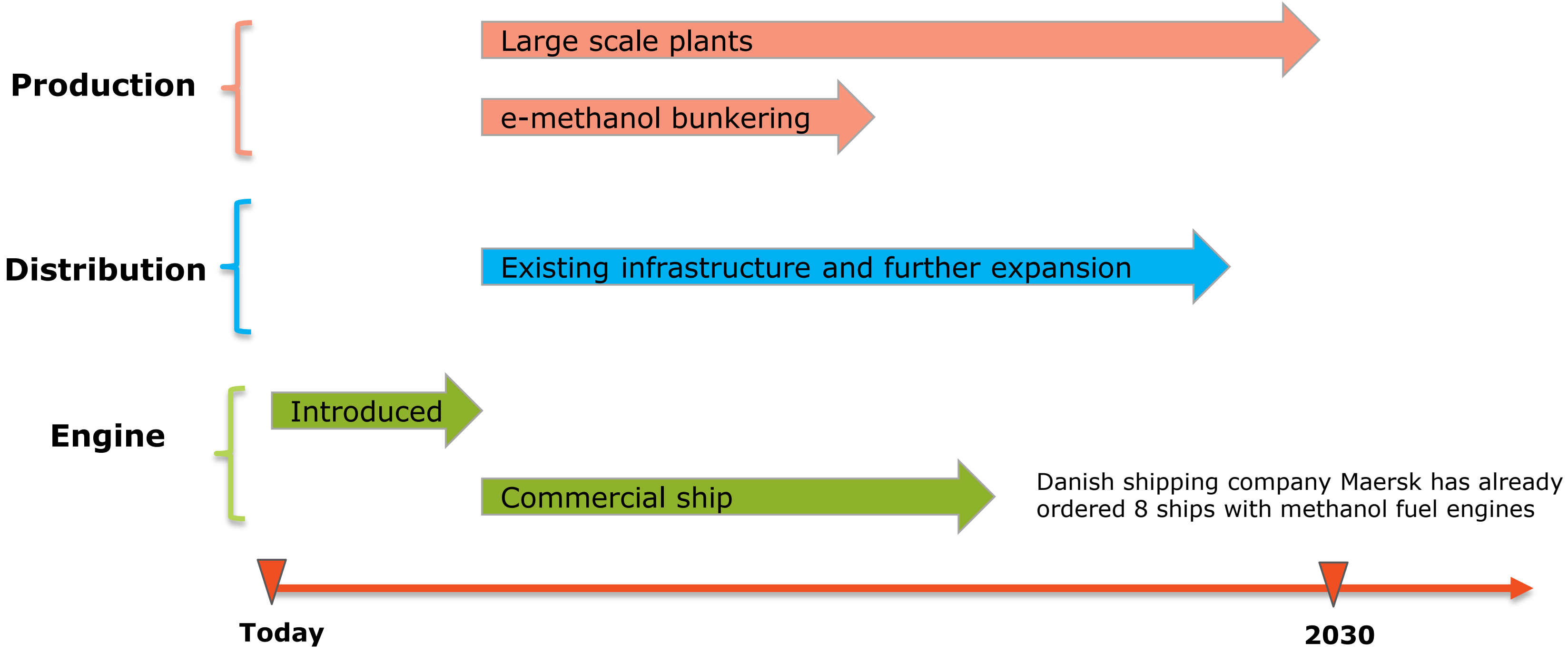
e-Ammonia Technology Status



e-Methanol Technology Status



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Opportunities for Ports

Transformational Change Over Decades

Renewable Energy Production

- Offshore Wind Supply Chain Manufacturing
- Offshore Wind Logistics / Staging Ports
- Wind, Solar H2 Component Shipping – Import & Export

Green Fuels Terminals

- Production Hubs
- Storage Facilities
- Import & Export Terminals

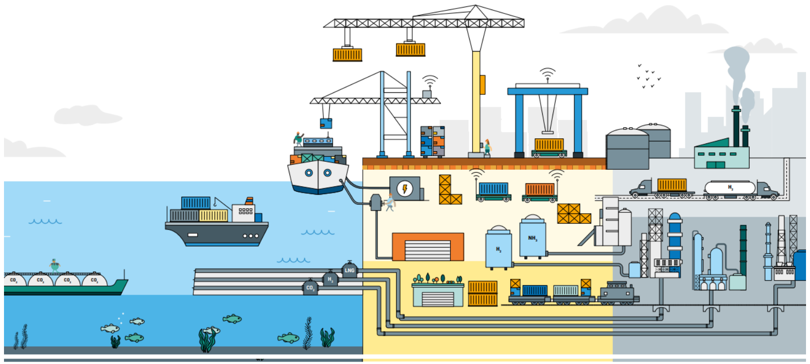
e-Fuels Bunkering Facilities

- Liquid & Gaseous e-Hydrogen Facilities
- e-Ammonia and e-Methanol Bunkering Facilities

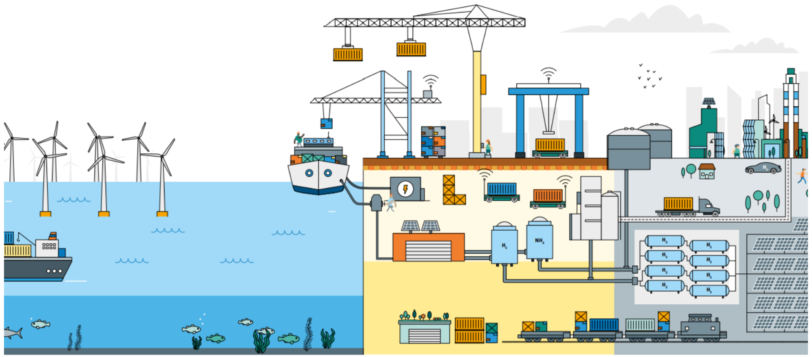
Raw Materials Handling Terminals

- Unlike fossil fuels, wind & solar require massive infrastructure upfront, then the fuel is free
- IEA: 6x more specialty materials required to build an electric car vs conventional vehicle
- IEA: 9x more specialty metals & minerals per MW of capacity for a wind farm vs a natural gas plant
- IEA: 6x more metals & minerals by 2040 to achieve net-zero goals by 2050
- In-demand metals and minerals include copper, nickel, manganese, cobalt, chromium, molybdenum, zinc, rare earth metals., lithium, graphite, silicon and others

Blue (clean) Hydrogen/Ammonia
supply chain



e-Ammonia / e-Hydrogen
supply chain



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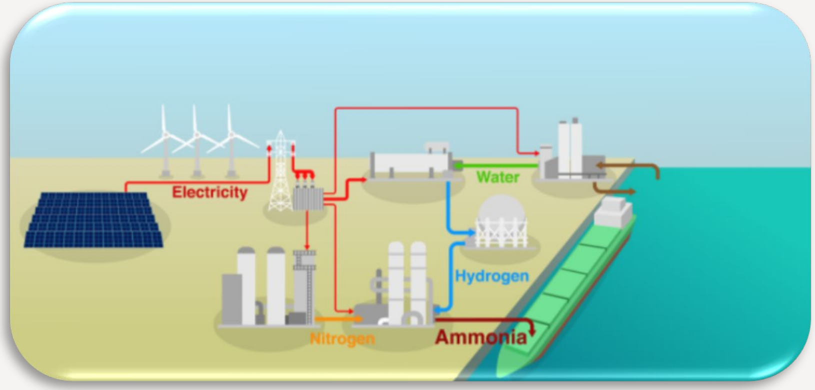
Example Projects

Example Projects

Green Ammonia Export Terminal

Confidential Client & Location, Middle East

- Solar PV Farm for Green Energy Input
- Electrolysis to Produce Green Hydrogen, then Converted to Green Ammonia for Export
- Export Terminal on Open, Exposed Coastline
- Very Efficient Marine Terminal Infrastructure



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Example Projects

e-Methanol Bunker Fuel Infrastructure

Confidential Client & Location, Global

- Renewable Energy Sourcing - ~10GW
- HV Transmission
- e-Methanol Production
- Marine Terminal for Export
- Multiple Facilities Globally

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Questions?

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Driver: EU Sustainability Criteria for e-Fuels

RED II Targets

32% Renewable Energy Consumption by 2030

- At least 32% of energy to come from renewable sources in the EU's gross final consumption of energy by 2030

14% Renewable Energy in Transport by 2030

- Sub-target on the share of renewable energy within the final consumption of energy in the transport sector. Aviation & maritime are not obliged but can contribute.

RED II GHG Savings

70% GHG emissions savings

- E-fuels must have at least 70% GHG emissions savings compared to fossil fuels from a life-cycle perspective

Policies: Global and US Clean/Green/e-Hydrogen

- Europe, China, South Korea by 2030 (examples)
  - Germany $10 billion / China $20 billion / South Korea $38 billion

- The US Bipartisan Infrastructure Law (BIL) provides
  - $8 billion for the development of at least four "regional" hydrogen hubs
  - $1 billion for the electrolysis technology development
  - Provides $20 billion for creating an Office of Clean Energy Demonstrations

- US DOE Earthshots initiative aims at $1 for 1kg clean hydrogen in 1 decade ("111")

- The proposed US "Build Back Better" bill
  - Production tax credit of up to $3/kg H2
  - Extending 30% investment tax credit (ITC) for solar to 2027