NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

Maritime Energy & Sustainable Development Centre of Excellence
College of Engineering

BIOFUELS

Sustainable Pathways of Biofuels for Maritime Application

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Introduction to biofuels

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Energy sustainability and energy transition

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What is “BIOFUEL”?

Liquid or gaseous fuels produced from biomass

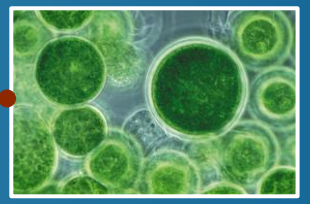
Through thermal, chemical and biochemical conversion, biomass can be converted into a variety of biofuel products.

Waste and genetically modified algae

Municipal waste, food processing waste, sewage sludge, organic waste, etc.

4th

3rd



Algae (macro and micro algae)

Lignocellulosic biomass and inedible oils

2nd

1st

Vegetable oils & animal fats and plants containing sugar & starch.

Emission of CO_2

Biofuels versus Fossil fuels

Both contain carbons but difference in CO_2 accountings

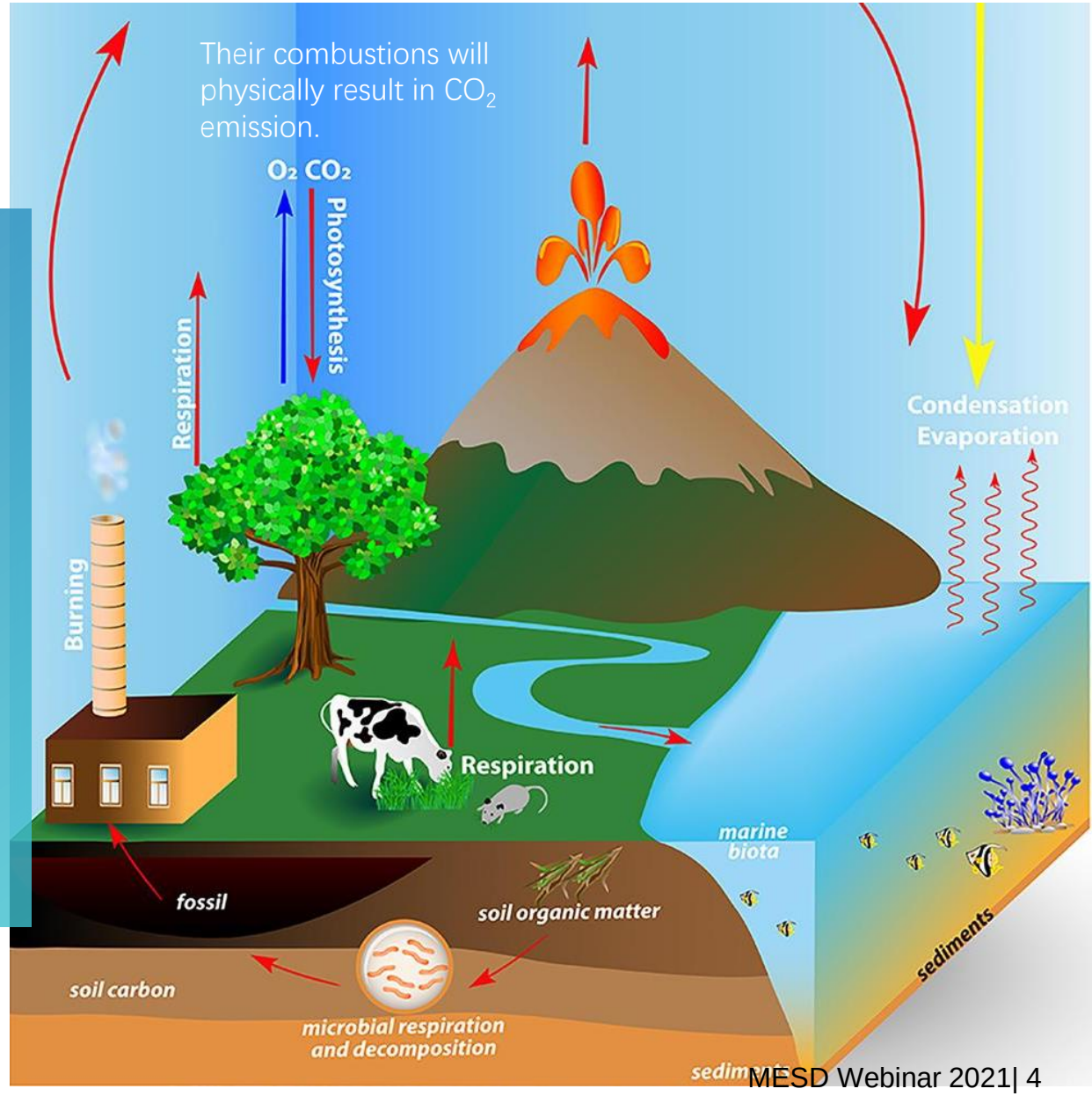
Carbons in biomass:

Accumulated via photosynthesis of plants to convert light energy (with water and CO_2) into energy stored in biomass.
Its burning releases carbons that have been absorbed as the plant grows.

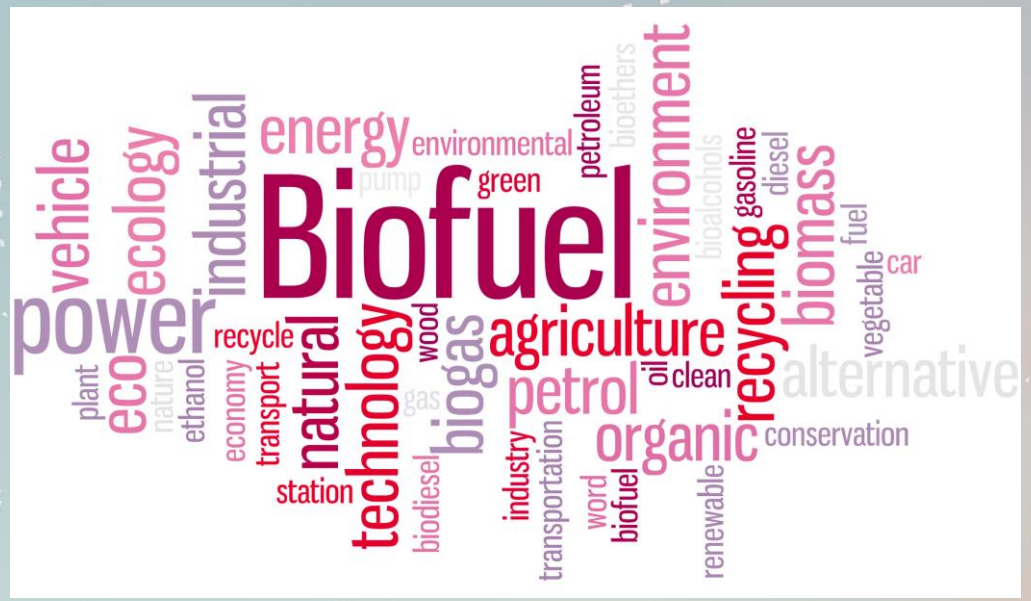
Carbons in fossil fuels

Accumulated over millions of years to its present forms (i.e. coal, oil and gas).
Its burning releases carbons that have been fixed in the ground millions of years to the atmosphere.

Therefore, CO_2 emissions from the combustion of biofuels "do not count towards the onboard emissions".



Questions to ponder about biofuels



MEASURES for shipping industry for short-, medium- and long-term? either as a drop-in fuel or as a substitute of conventional fossil-based fuels?

REALISTIC?

(availability, cost, etc.)

TYPES OF BIOFUELS?

FUTURE PROOF?

A DROP-IN FUEL OR A SUBSTITUTE?

LEVEL OF CONTRIBUTION

to CO_2 emission reduction?

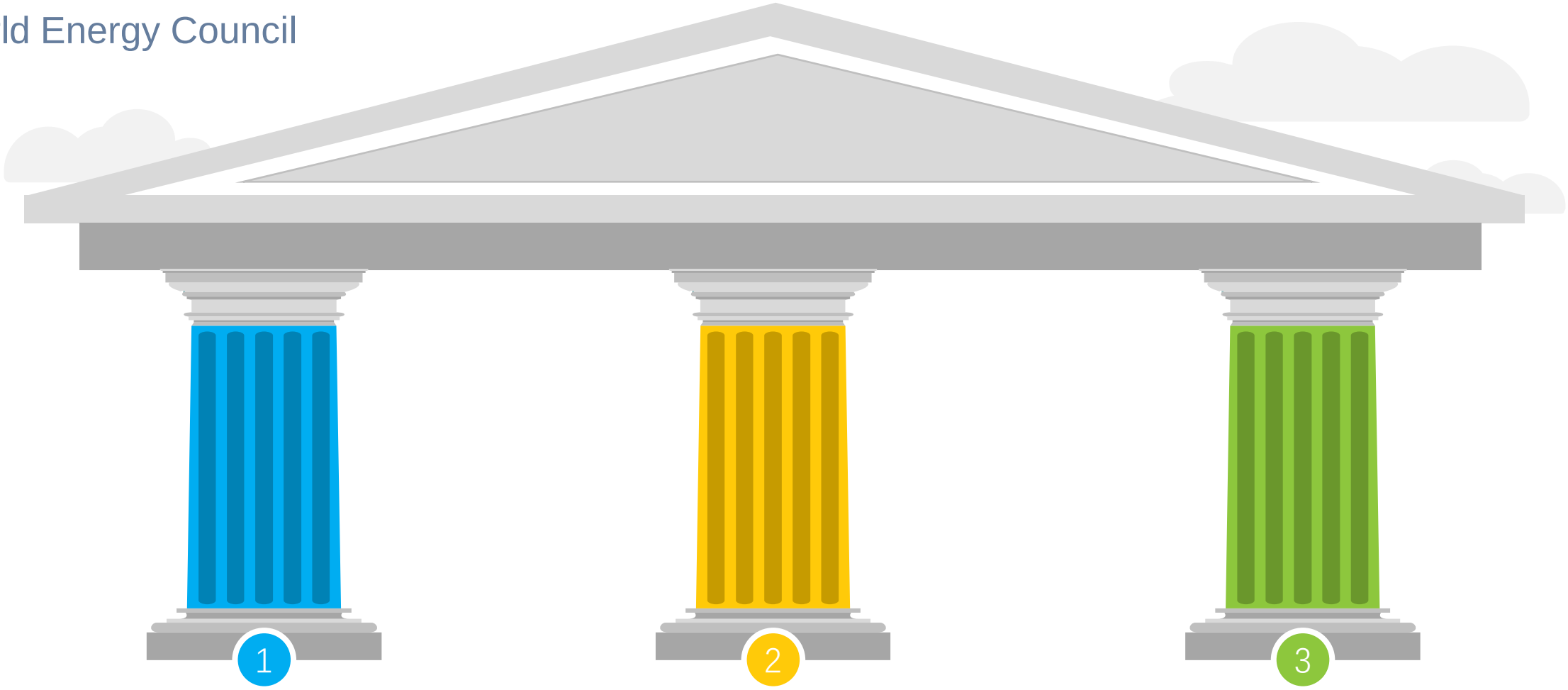
ISSUES?

(Technical, operational)

WHAT TO FOCUS FOR THE DEVELOPMENT?

Sustainability of energy system

World Energy Council



Energy security

Effective management of energy supply, reliable of energy infrastructure, and ability to meet the current and future demand

Environmental sustainability

Energy efficiency and supply from renewable and other low carbon sources

Energy equity

Accessibility and affordability

Crucial steps enabling energy transition

A small group of consumers are willing to pay a premium for the energy services attached to the new technology.

A full energy transition is crucially governed by the price of the energy service.

A successful new technology or energy source must provide the same service with superior or "additional characteristics"

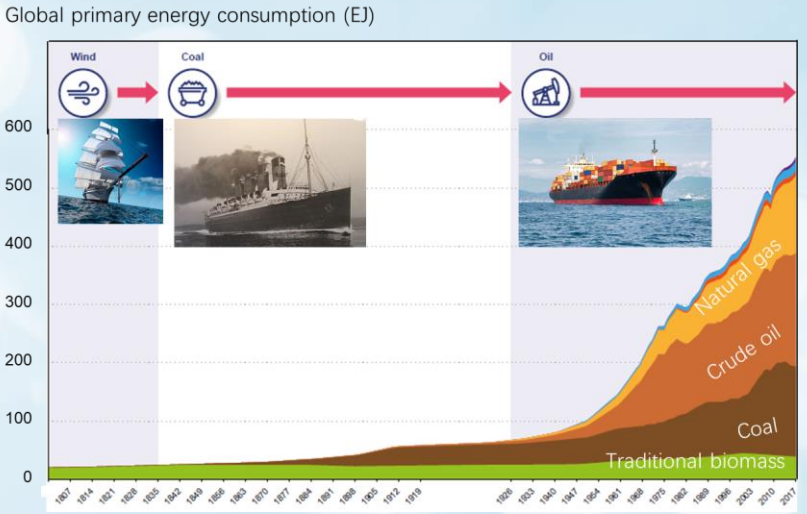
Full energy transition

Reduction in cost of technology and energy

Prototyping by end-users

Emergence of technology

Over time, economies of scale improves the technology and the price of the energy source, driving down the "cost of generating energy services", making it competitive with the incumbent energy technology and source.



Potential types of biofuels for shipping sector

Shortlisted based on: Their TRL of the production process and existing shipboard energy system with trends of the development.

Straight vegetable oil

Biodiesel (FAME)

Hydrotreated vegetable oil

Pyrolysis oil

Bio-LNG

Biohydrogen

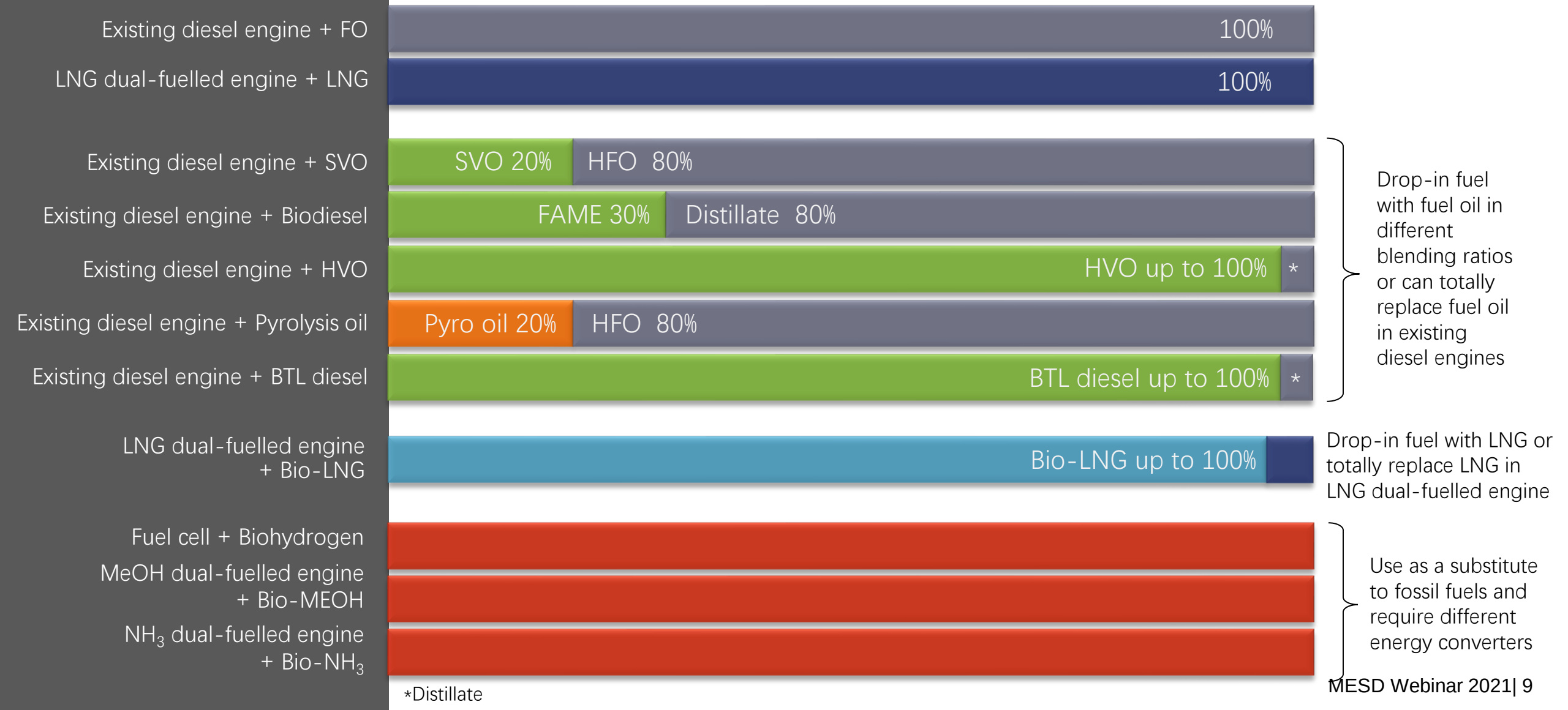
Biomethanol

Bioammonia

BLT diesel

Use as a fuel onboard ships

From data reported in literatures, the use of biofuels as a fuel onboard ship is summarised.



*Distillate

Global potential of biomass feedstock in 2050

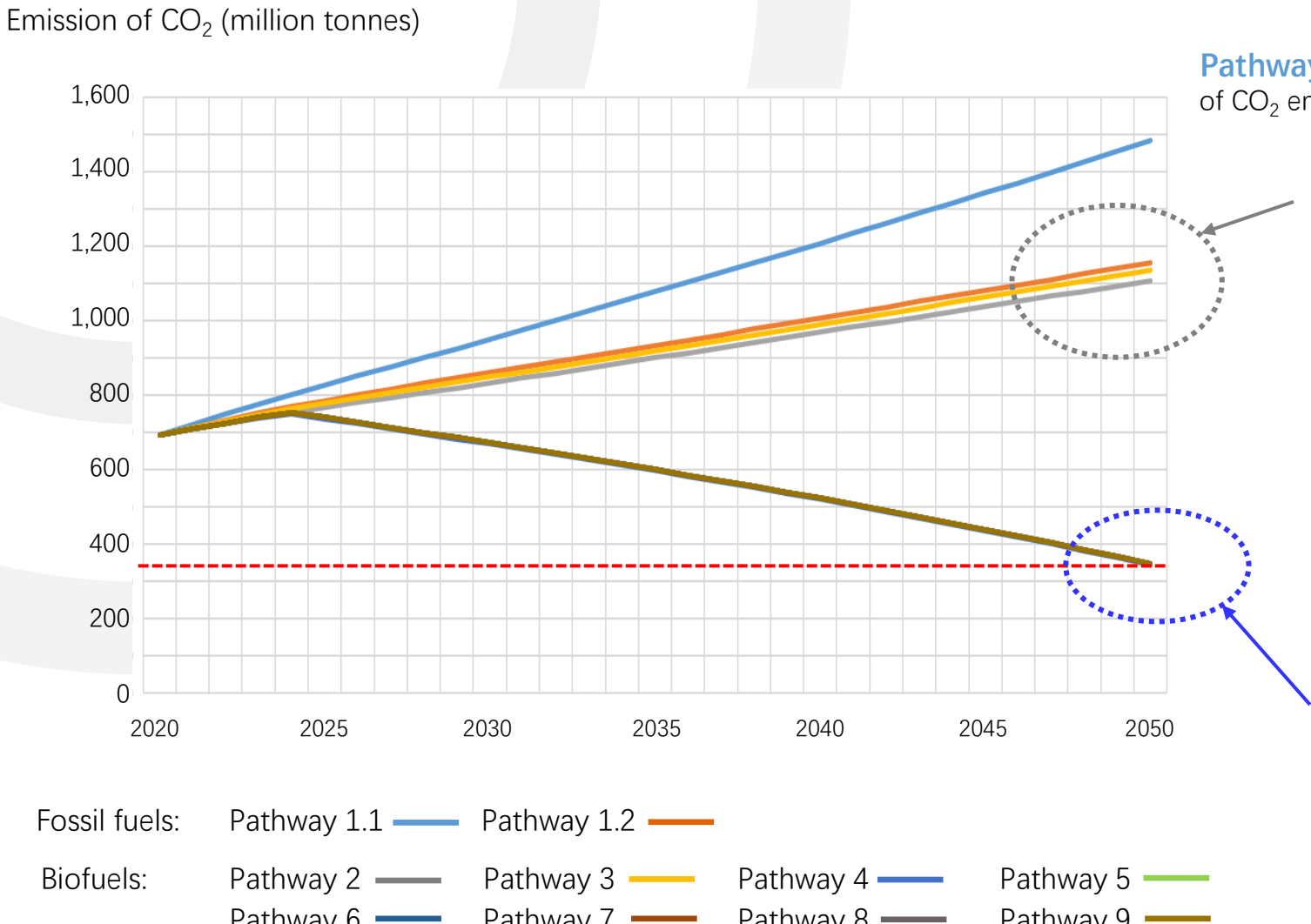
World Bioenergy Association

To evaluation the potential availalbity of biofuels, the data on global potential of biomass feedstock is necessary.

Resources	Energy Production (EJ)			Biomass Production (million tonnes)		
	Low	High	Average	Low	High	Average
1. From agriculture						
1.1) Energy crops: dedicated crop as main products						
· Energy farming on current agricultural land	100	300	200	5,263	15,789	10,526
· Biomass production on marginal lands	60	110	85	3,158	5,789	4,474
1.2) By products and residues including manure						
· Residues from agriculture	15	70	43	789	3,684	2,237
· Manure	5	55	30	263	2,895	1,579
Total from agriculture	175	480	328	9,211	25,263	17,237
2. From forestry						
- Forest residues	30	150	90	1,579	7,895	4,737
3. Organic waste						
- Municipal and industry	5	50	28	263	2,632	1,447
Total	**210**	**680**	**445**	**11,053**	**35,789**	**23,421**

Note:
The data of energy production (EJ) is from International Energy Agency, 2013).
Biomass production is calculated from heating value of biomass (0.019 EJ/ million tons of dry biomass) (International Energy Agency, 2013).

What are the potential pathways to meet CO_2 emission target in 2050?



Pathway 1.1: Using fuel oils results in highest growing rate of CO_2 emission

Unable to meet emission target in 2050

Pathway 1.2: Using fossil-based LNG

- Low CO_2 monetary value to enable the adoption

Pathway 2: Using B30

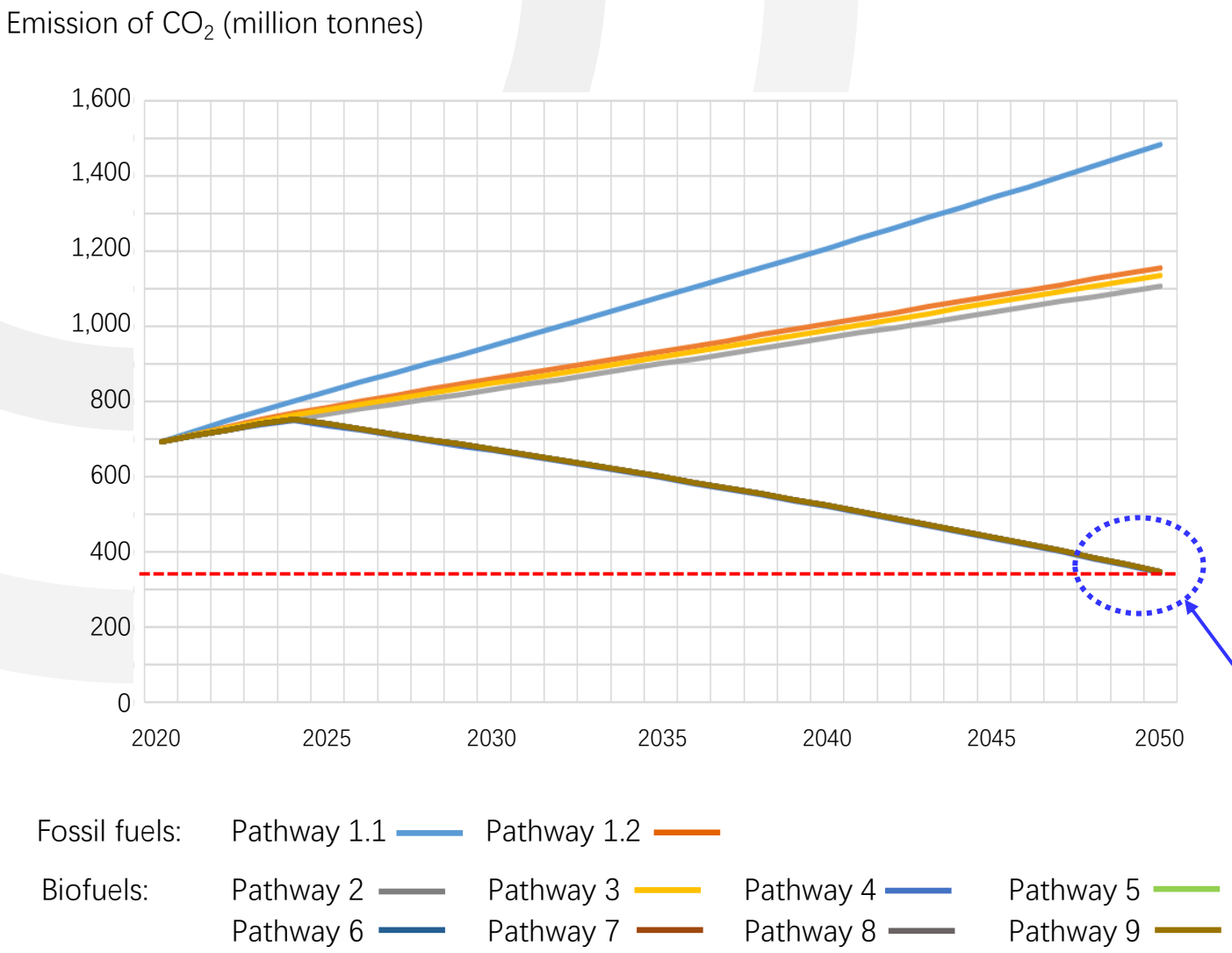
- Medium CO_2 value to enable the adoption
- Also, with the adoption of LNG (economic decision)

Pathway 3: Using pyrolysis oil-blended LFSO (20%)

- Low CO_2 value to enable the adoption
- Its adoption is not as attractive as that of fossil-LNG.

Able to meet emission target in 2050 but are they realistic?

Are they realistic pathways to meet CO_2 emission target in 2050?



Pathway 4: Using HVO to substitute fuel oil

- High CO_2 monetary value to enable the adoption
- Competing use of feedstock for biodiesel and competing use of HVO with aviation sector.
- Issue on availability, without 3rd gen feedstock, it is likely to be "unrealistic".

Pathway 6: Using biohydrogen

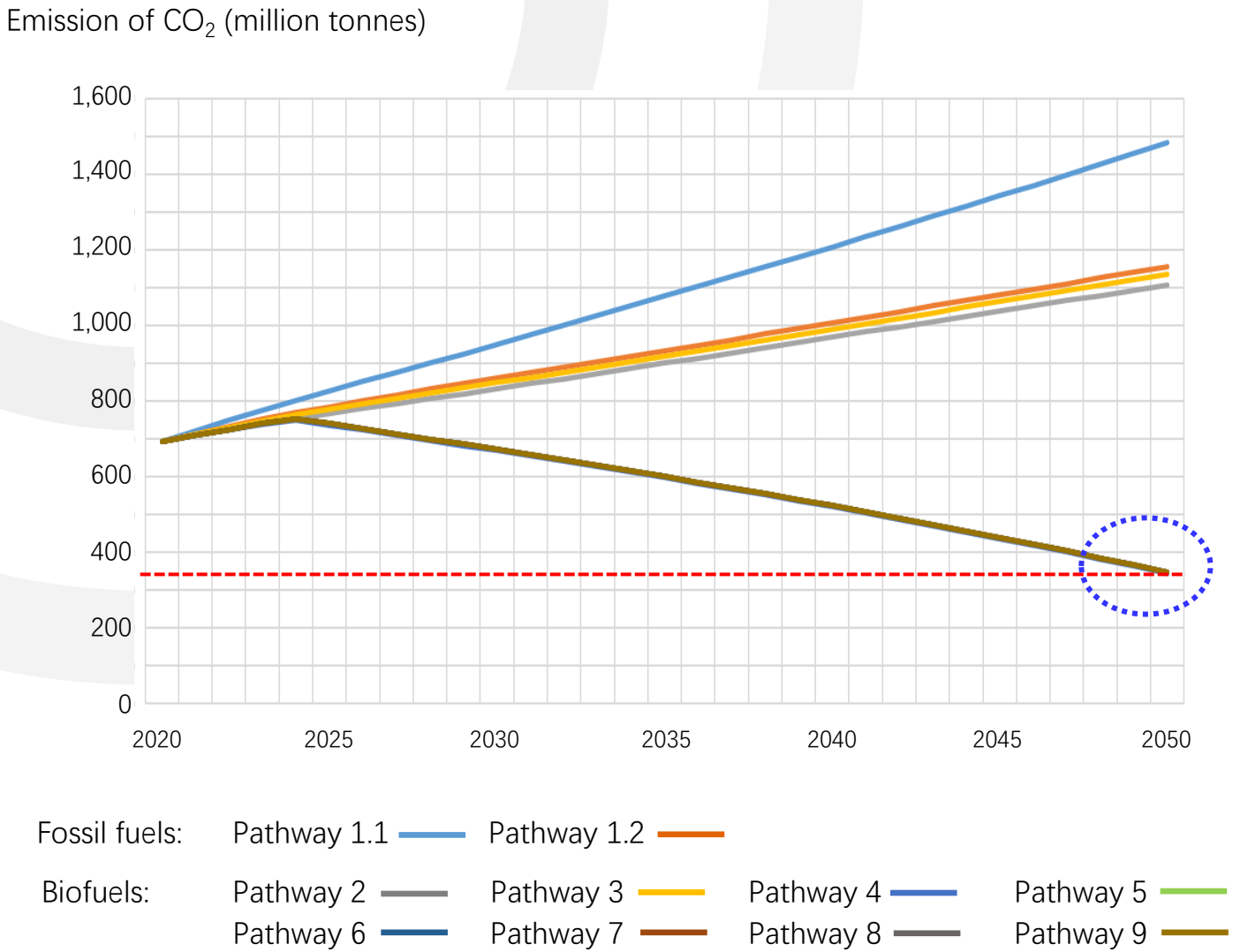
To enable the adoption, it is required:

- High CO_2 monetary value to enable the adoption
- Substantial reduction of biohydrogen cost is required
- Production technology of bio-H_2 is relative mature (compared to that of non-bio renewable H_2)
- Also, biomass feedstock is much more limited compared with non-bio renewable energy.
- Identified as "not favorable pathways"

Pathway 7: Using bioammonia: Similar with Pathway 6

Able to meet emission target in 2050 but are they realistic?

Are they realistic pathways to meet CO_2 emission target in 2050?



Having a potential to be considered "sustainable".

Pathway 5: Using bio-LNG to substitute fossil fuel

To enable the adoption, it is required:

- High CO_2 monetary value to enable the adoption
- Slight decrease in bio-LNG cost
- Potential supply seems to be sufficient but competing use with other sectors

Pathway 8: Using biomethanol to substitute fossil fuel

To enable the adoption, it is required:

- High CO_2 value to enable the adoption
- Substantial reduction of biomethanol cost
- Potential supply seems to be sufficient but possibly competing use with other sectors

Pathway 9: Using BTL diesel to substitute fuel oil

To enable the adoption, it is required:

- High CO_2 value to enable the adoption
- Substantial reduction of biohydrogen cost
- Its cost has potential to be lower due to FT synthetic process.
- Potential supply seems to be sufficient but possibly competing use with other sectors

Fuel oils
LNG

Now

2030

2050

Biodiesel:
As a drop-in fuel with distillates (B30)

HVO:
As a substitute to fuel oil

Applicable with existing ships and bunkering infrastructure with minor modifications.

Bio-LNG:
As a drop-in fuel with LNG or a substitute to LNG

Could be considered as a drop-in fuel with LNG when its supply is limited during the establishment of the value chain for shipping industry.

Its mixing ratio can be increasing over time as its supply is more available.

Biomethanol:
As a substitute to fossil fuel

BTL diesel:
As a drop-in fuel with distillate or a substitute to fuel oil

Together with Bio-LNG and B30, the adoption of biomethanol could become dominant (especially, when it is commercially available with cost reduction.)

Non-bio renewable hydrogen and its carriers:
- Green H_2 and green ammonia
- Synthetic LNG
- Synthetic methanol

Ideal fuels for long-terms, particularly due to their potential availability and environmental benefits from life cycle perspectives.

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