TRANSPORT & ENVIRONMENT

Zero emission maritime transport

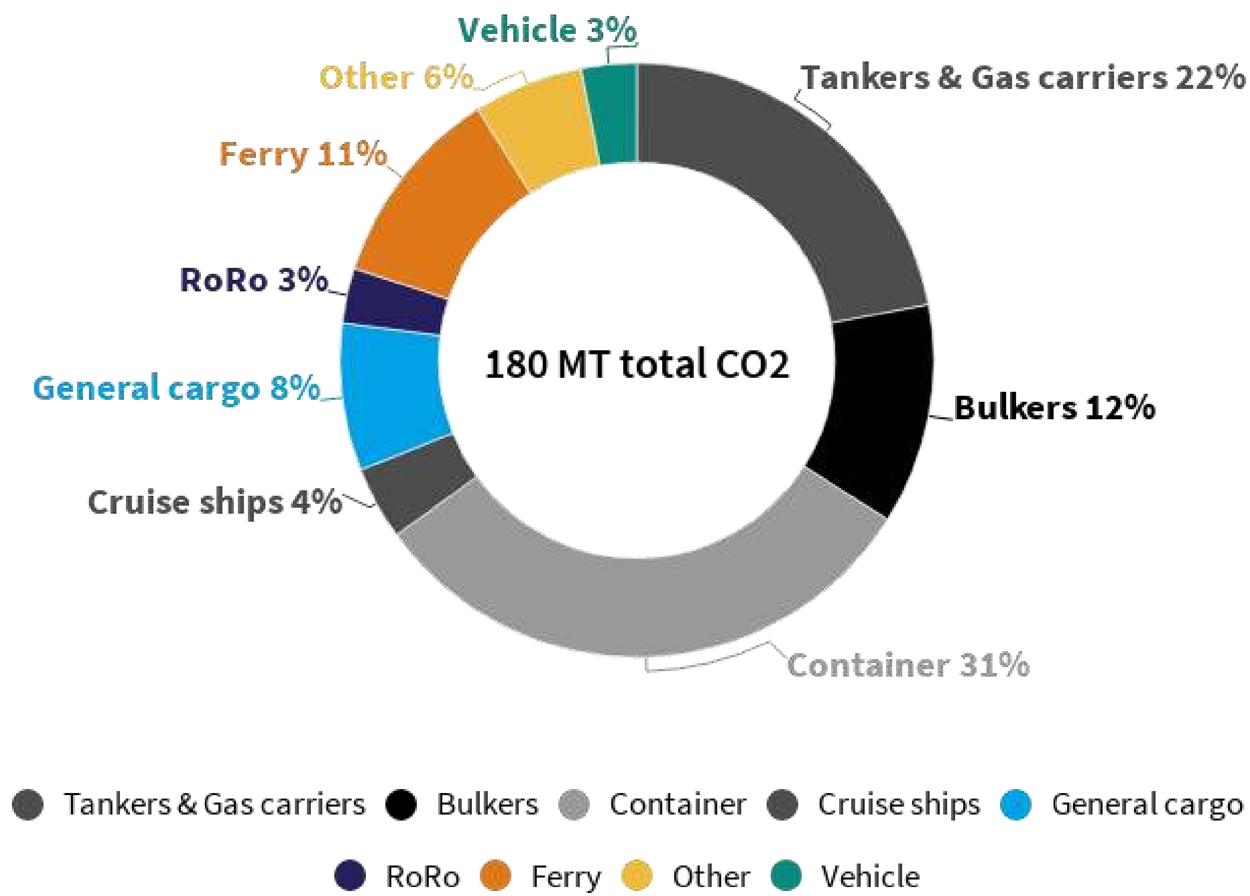
Roadmap to decarbonising European Shipping

SUSTAINABLE ENERGY WEEK

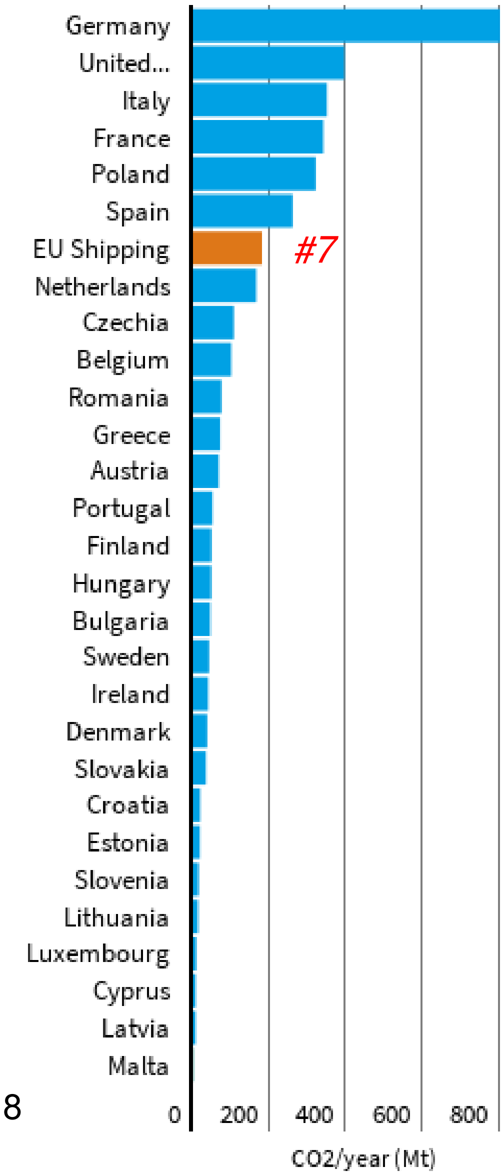
2019
Faig Abbasov

How big a problem?

EU shipping CO_2



EU CO_2



Source: Ricardo-AEA, 2013 for the EU MRV impact assessment scope; Eurostat, 2018

Myth: ‘Dieselgate’ – cars are main culprit. Shipping is part of the solution.

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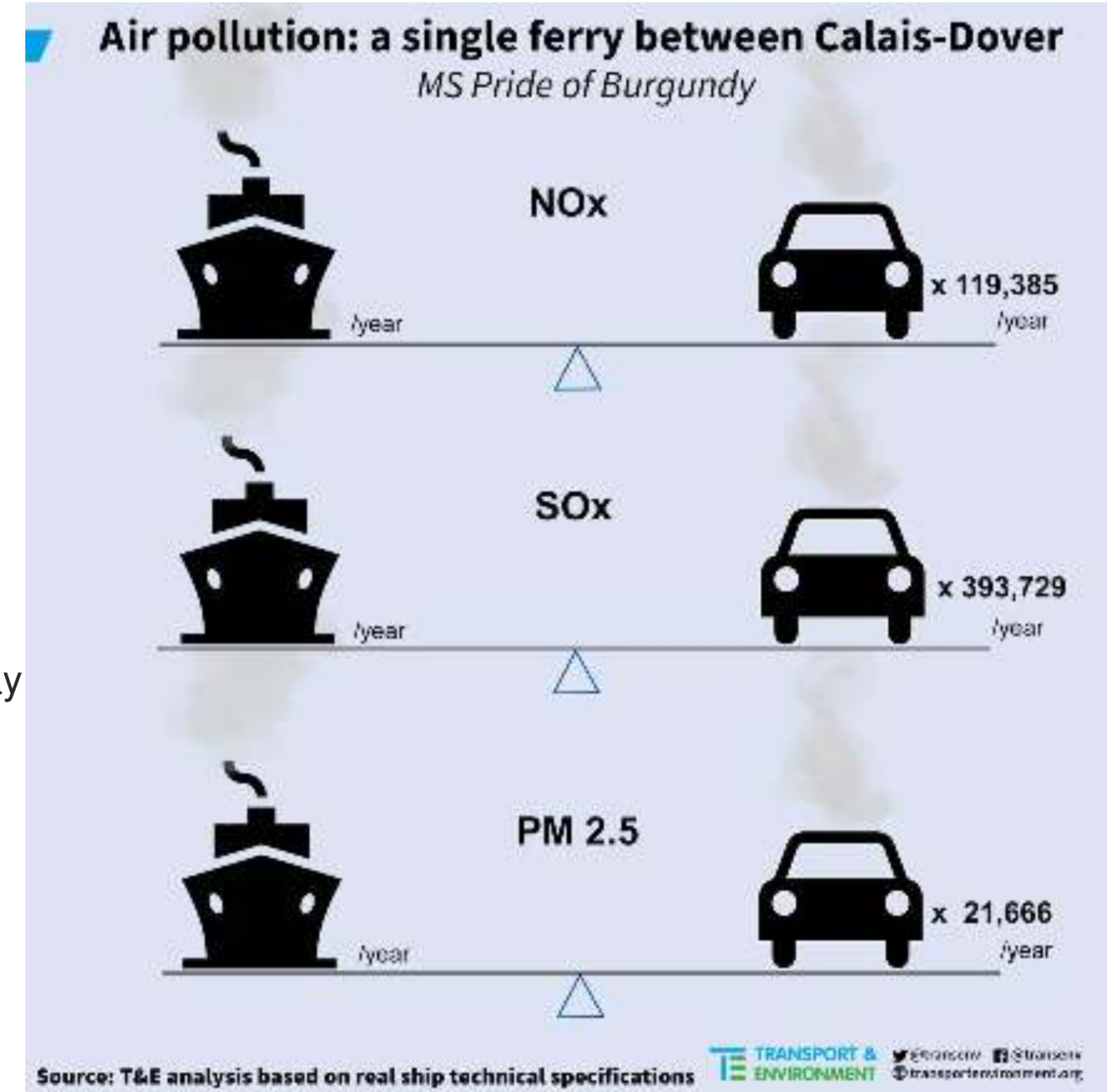
Journey:
Calais-Dover

Ship:
PoB (~1420 pax, 530 cars)

Distance:
21 n-miles

Operational profile:
209 days/year, 6 journeys/day

Fuel:
MGO, 1000ppm S
Road diesel, 10ppm S



Principles of ZERO emission future

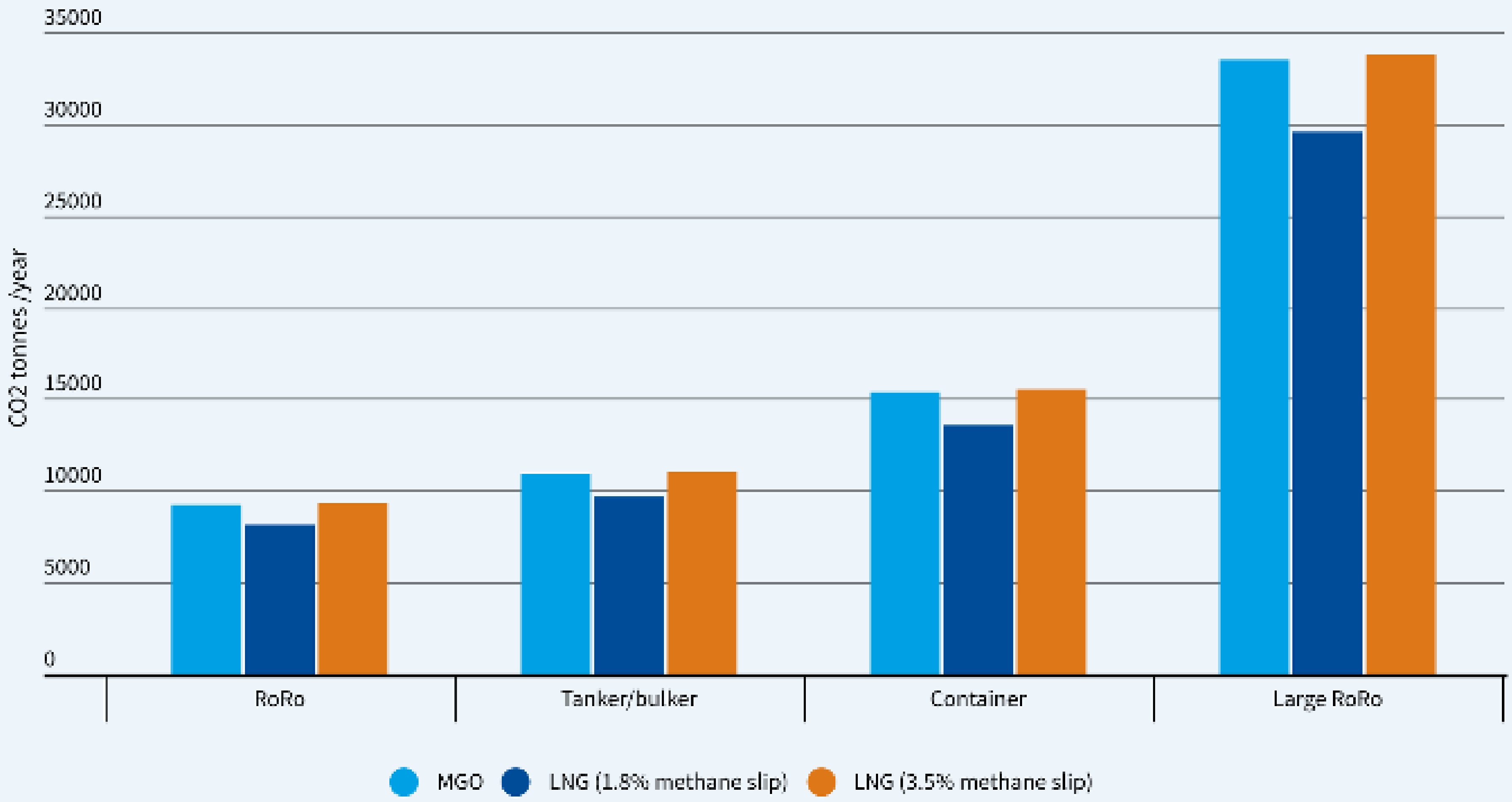
- **Technical feasibility**
- **Climate benefits** (without environmental degradation)
- **Sustainably scalable**
- **Responsible consumption**
- **'Primus inter pares'** (*cheapest* among the equals)
- **Enforceability**

Marine fuels/energy

- LNG – Liquified Natural gas
- Biofuels
- Electricity & e-fuels
  - e-H2 - hydrogen
  - e-NH3 - ammonia
  - e-CH4 – synthetic methane
  - e-gasoil – synthetic gasoil

LNG

Annual CO2eq emissions per ship (MGO vs. LNG)



Source: Ricardo Energy & Environment, 2016

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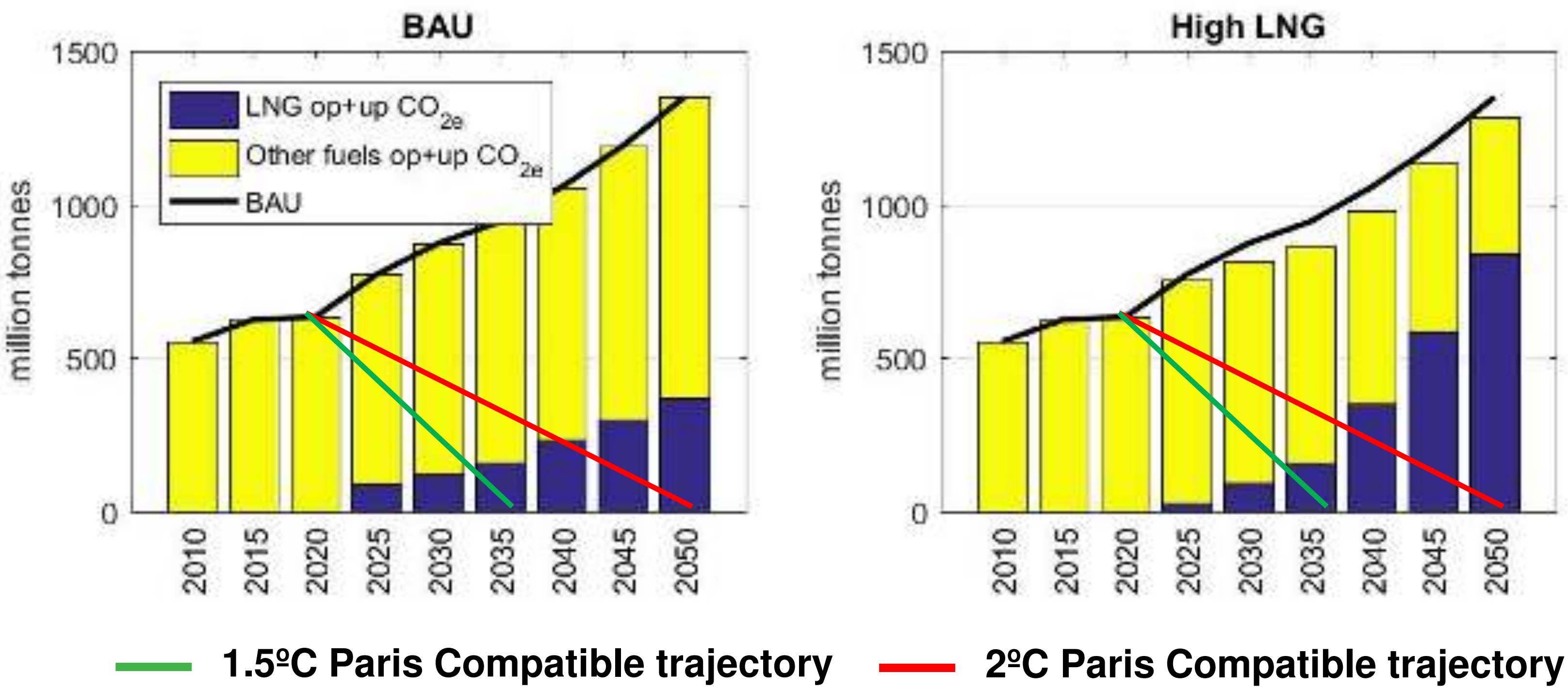
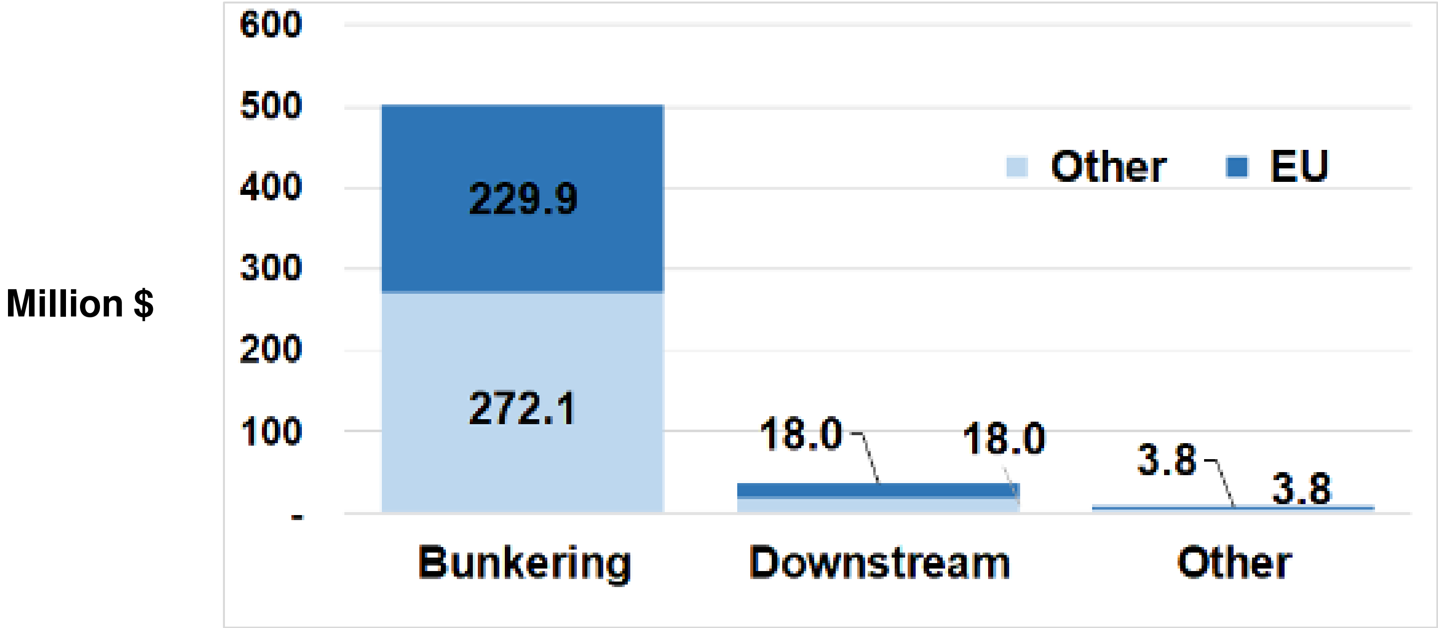
GHG benefits of LNG vs. BAU



- Shifting 60% of global fleet to LNG will deliver only **4.6%** GHG reduction from ships on well-to-wheel (well-to-wake) basis compared to business-as-usual (BAU).
- Cumulative emissions (well-to-wake) from 2010-2050
    - **BAU - 35.22 billion tonnes**
    - **High LNG scenario - 33.61 billion tonnes**

Source: Forthcoming research, UCL/UMAS (2018

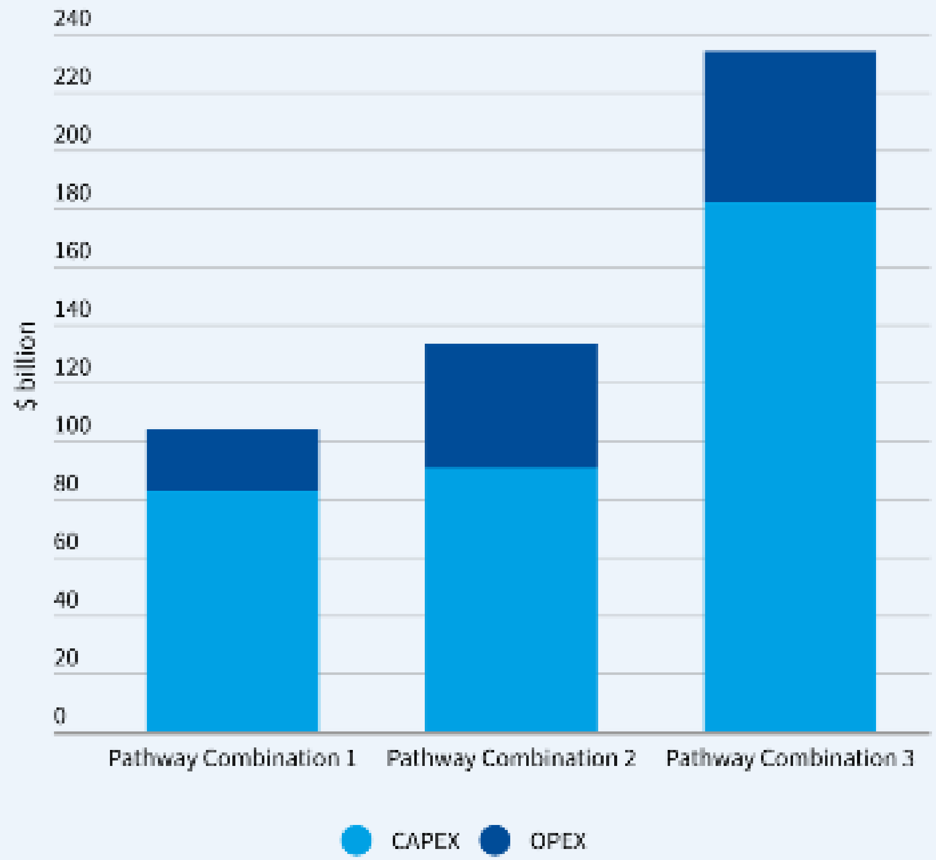
Investment & stranded assets



Funding:	"BAU"	"High Gas"	"Transition"	"Limited Gas"
Private funding:	4,296	11,055	2,002	957
EU-2050:	4,763	9,992	2,486	1,028
EU-2025/30:	1,525	1,158	1,036	952
Total:	10,584	22,205	5,524	2,937

Source: Domagoj, B (2018) UMAS

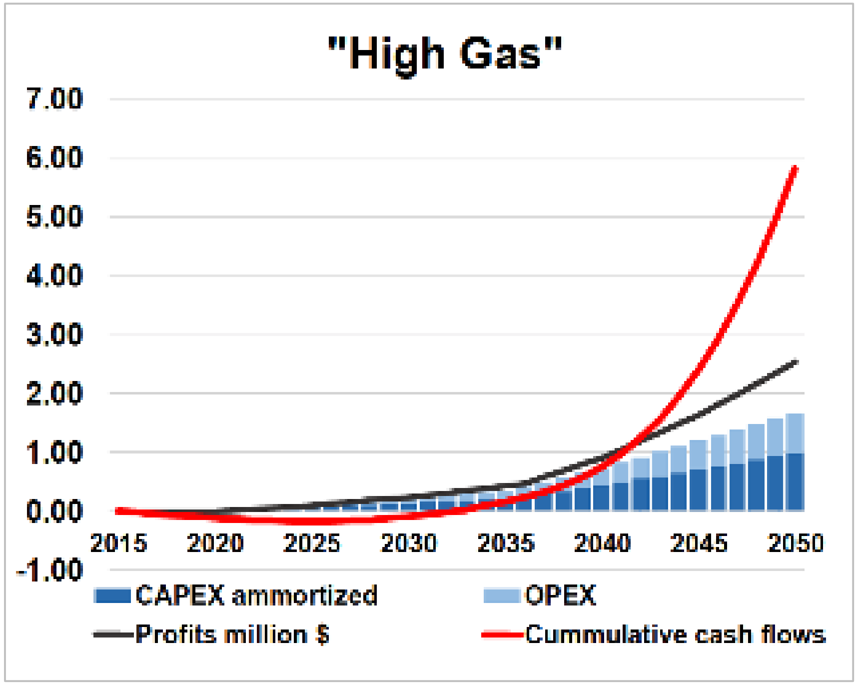
Ship LNG bunkering infrastructure costs

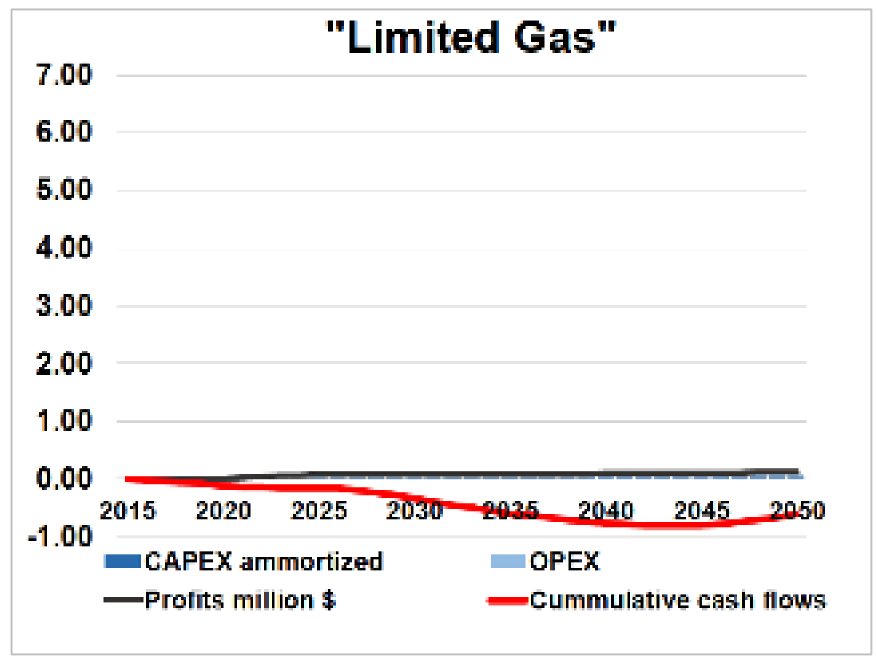


	Combination 1	Combination 2	Combination 3
Direct bunkering	10%	5%	27%
LNG feeder vessel	80%	45%	27%
LNG storage tanks	5%	45%	27%
LNG barge	5%	5%	20%

Source: forthcoming research UCL/UMAS (2018)
Note: estimations assume 3-61% market share increase of LNG from 2025 to 2

Stranded assets – case of LNG





Source: UMAS/UCL, 2018

LNG – verdict?

✓ **Technical feasibility**

✗ **Climate benefits** (without environmental degradation)

✗ **Sustainably scalable**

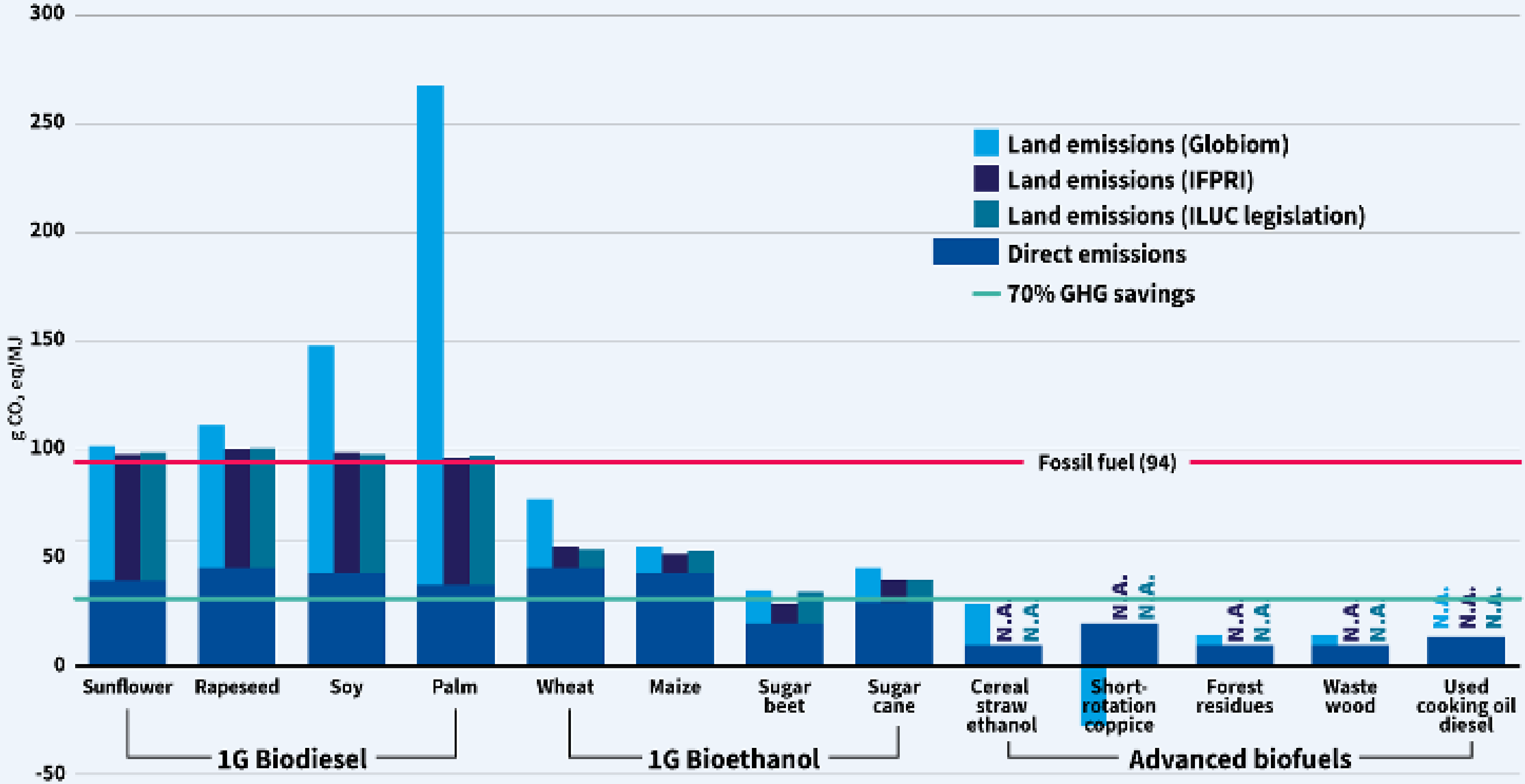
✗ **Responsible consumption**

✗ **‘Primus inter pares’** (*cheapest* among the equals)

✓ **Enforceability**

Biofuels

Direct emissions plus land emissions



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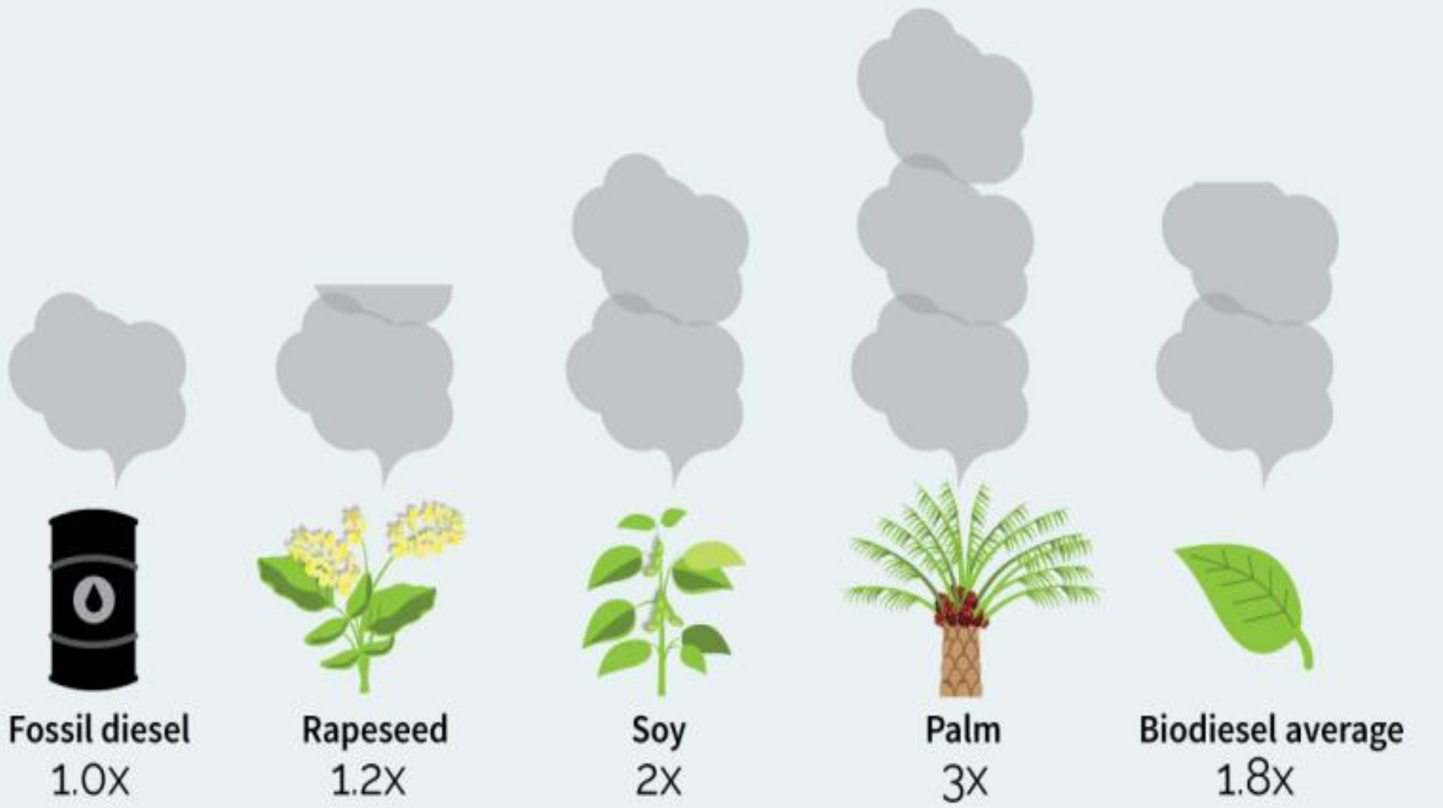
Source: RED II, ILUC directive, Globiom, IFPRI

EU BIODIESEL



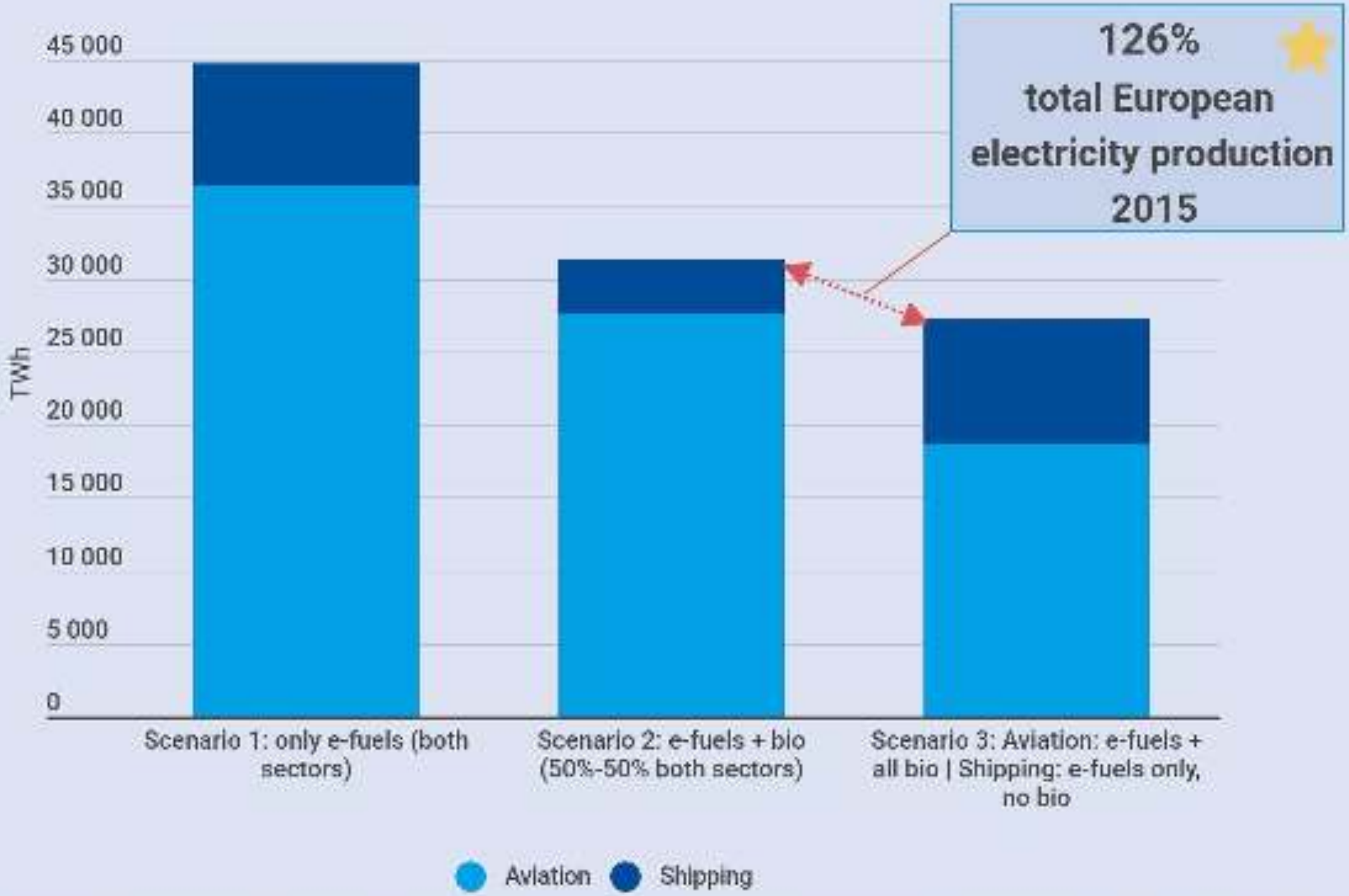
Crop-based biodiesel on average 80% worse for climate than fossil diesel.

Crop biofuels in shipping

Shipping energy demand 2017 **291 Mt HFO**
= 281 Mtoe
=11.8 EJ
= 134 Mha palm oil plantations (88GJ/ha, or 2660 l/ha)
= 1.34 Million km2 of palm oil plantations
= size of **twice France**

Shipping energy demand 2050 **436 Mt HFO (50% growth)**
=421 Mtoe
= 17.78 EJ
= 201 Mha Palm oil plantations (88GJ/ha, or 2660 l/ha)
= 2 Million km2 of palm oil plantations
= **Indonesia**

Global energy demand 2050: ships & planes



Calculations assume 50% and 250% energy demand growth for global shipping and aviation respectively by 2050. Synthetic kerosene is as assumed to be an alternative choice for aviation, while renewable liquid hydrogen is assumed for shipping. Analysis use 3.2Mj/Mj expended energy for synthetic kerosene and 1.74 Mj/Mj expended energy for liquid hydrogen.

Biofuels in shipping: challenges of regulation & enforcement

- **"Collective action" problem and the mobility of shipping's bunkering** – Ships and bunker suppliers have a tendency to avoid high prices and strict regulation.

- **Vested interests and the challenges of a global agreement** – the biggest non-sustainable biofuel and bio-feedstock suppliers are powerful nations, Brazil, Argentina, the US, Colombia, Indonesia, Malaysia, Liberia, etc.

- **Challenges of port state control (PSC) mechanisms** – In principles, PSC could consider additional sustainability criteria for biofuels, but this suffers from at least 3 shortfalls:
  1. **Disadvantaging local producers/suppliers** - if applied to only locally sold fuel, ships will bunkers elsewhere.
  2. **Difficult to distinguish** - If applied to fuels ships use and carry, it is physically impossible to identify the origin and the upstream emissions of the bio-feedstock used.
  3. **International trade wards** - This could also create international political crises (current example in road transportation: *Reuters: Malaysia trade ministry to approach WTO on EU move to limit palm oil use* [access link].

Biofuels – verdict?

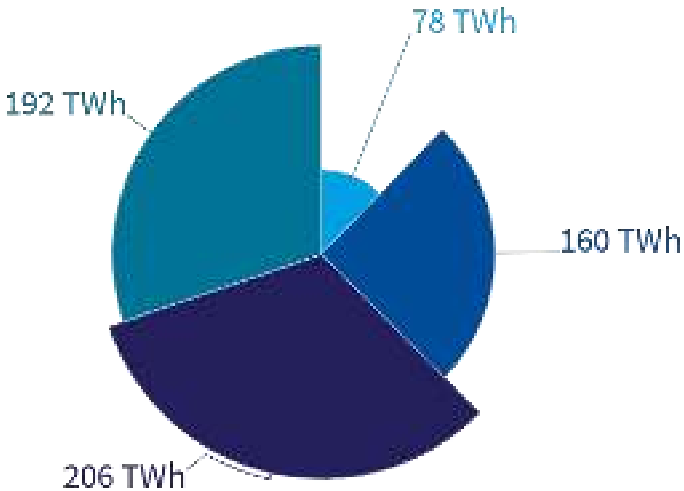
- ✓ **Technical feasibility**
- ❍ **Climate benefits** (without environmental degradation)
- ✗ **Sustainably scalable**
- ✗ **Responsible consumption**
- ✗ **‘Primus inter pares’** (*cheapest* among the equals)
- ✗ **Enforceability**

Electro-
fuels

How much renewable energy?

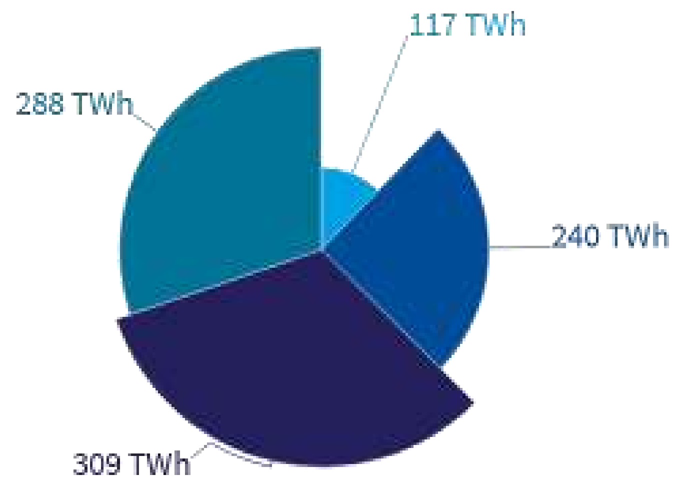
EU Shipping Energy Demand

2010



639 TWh

2050



959 TWh

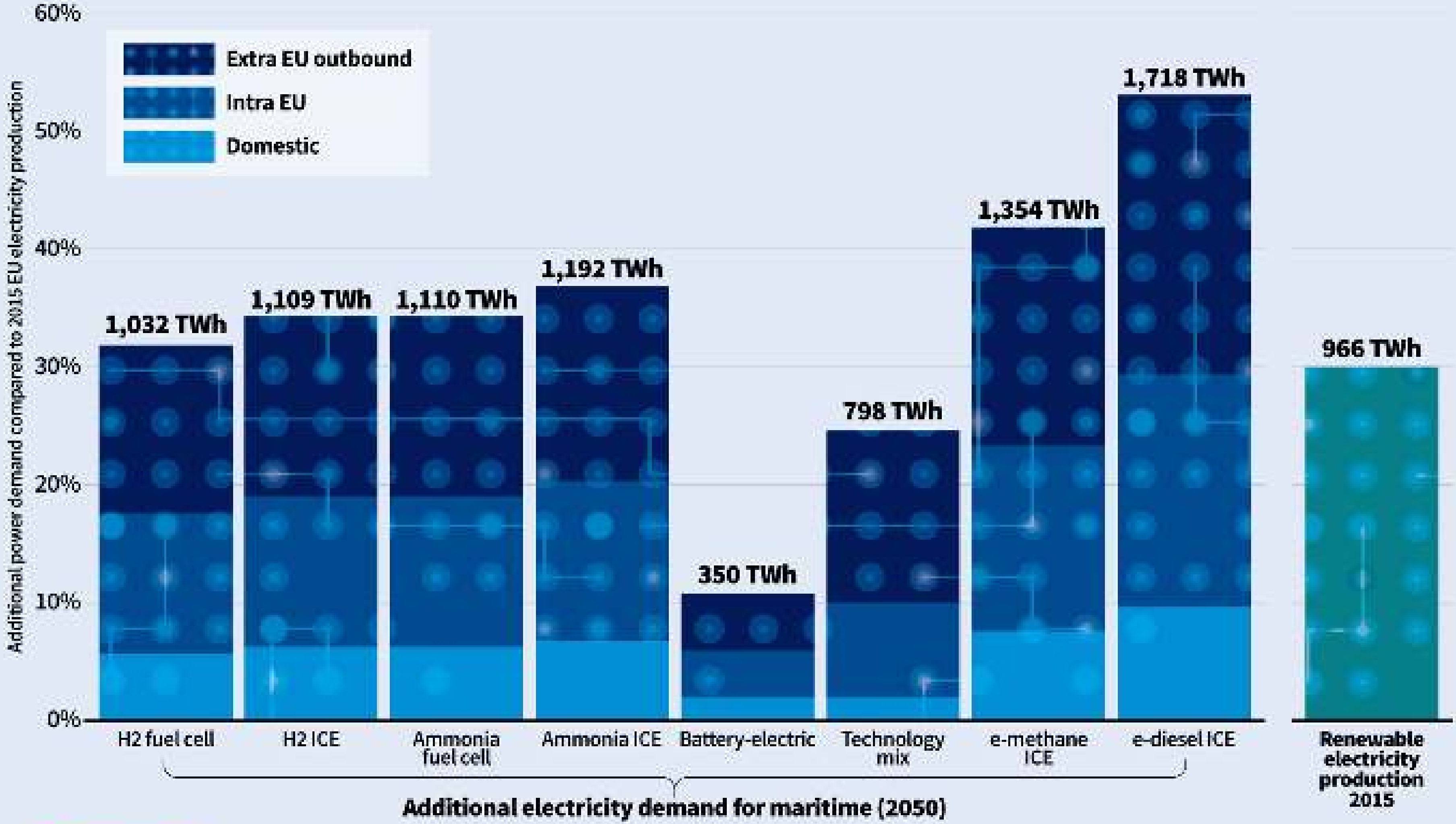
Domestic • Intra EU • Extra EU inbound • Extra EU outbound

Source: T&E 50% growth assumption based on Ricardo-AEA, 2013 for the EU MRV impact assessment scope;

Technology pathways analysed

Technology	Propulsion	Energy storage
Battery ships	Electric motor	Batteries
Hydrogen fuel-cells	Electric motor	Liquid H_2
Hydrogen ICE	Internal combustion engine (ICE)	Liquid H_2
Ammonia fuel-cells	Electric motor	Liquid ammonia
Ammonia ICE	ICE	Liquid ammonia
Electro-methane	ICE	Synthetic methane from electricity
Electro-diesel ICE	ICE	Synthetic diesel from electricity
Technology mix	Battery-electric, H2 fuel cell & Ammonia fuel cell	

Shipping's additional electricity demand under different technology pathways in 2050



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Source: Transport & Environment (2018)

How much renewable energy?

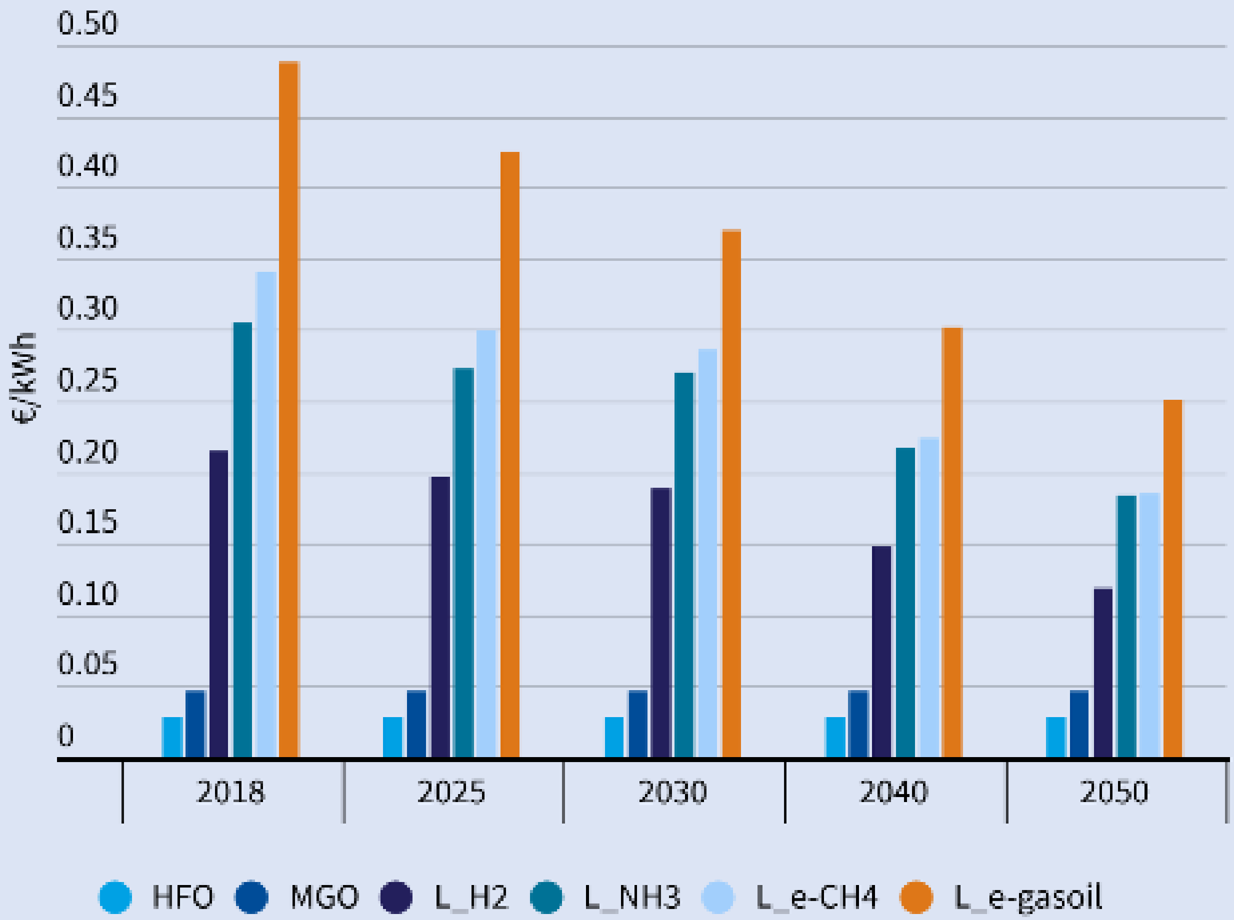
+11-53%	Additional renewable electricity over total 2015 electricity production

+11%	Battery-electric	*difficult*
+25%	Tech. mix: battery, liquid H_2 & NH_3	***more likely***
+32-34%	H_2 (FC & ICE)	*possible*
+34-37%	Ammonia (FC & ICE)	*possible*
+42%	Synthetic methane	*dangerous*
+53%	Synthetic diesel	*dangerous*

Sustainability & Enforcement

- **Upstream sustainability** – source of CO_2 synthetic hydrocarbons
- **Fugitive methane** – transmission/bunkering leakage & engine slip
- **Enforcement** – how to distinguish from fossil equivalents?
- **Stranded investments** - LNG bunkering

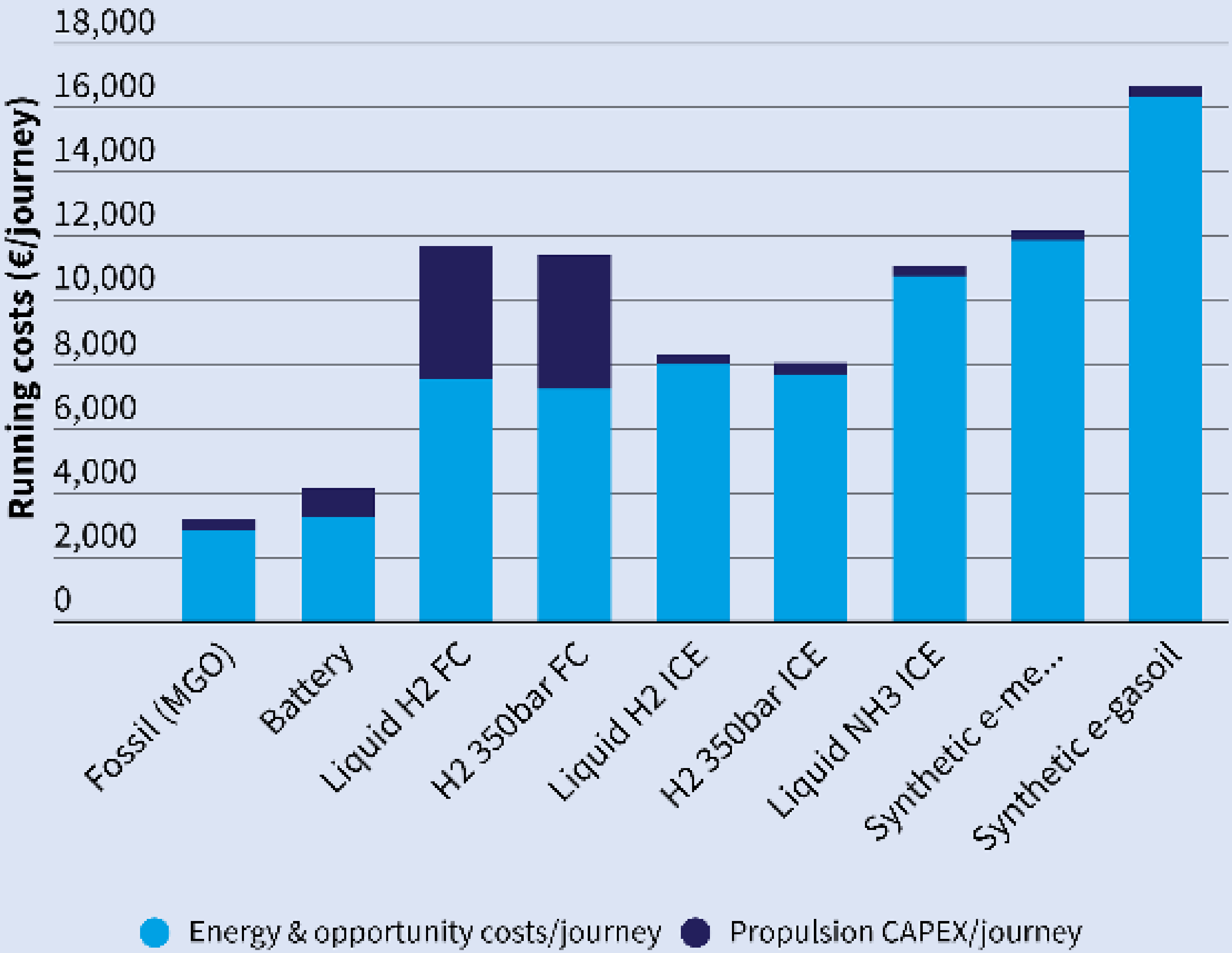
Fossil prices and e-fuel production costs (base case)



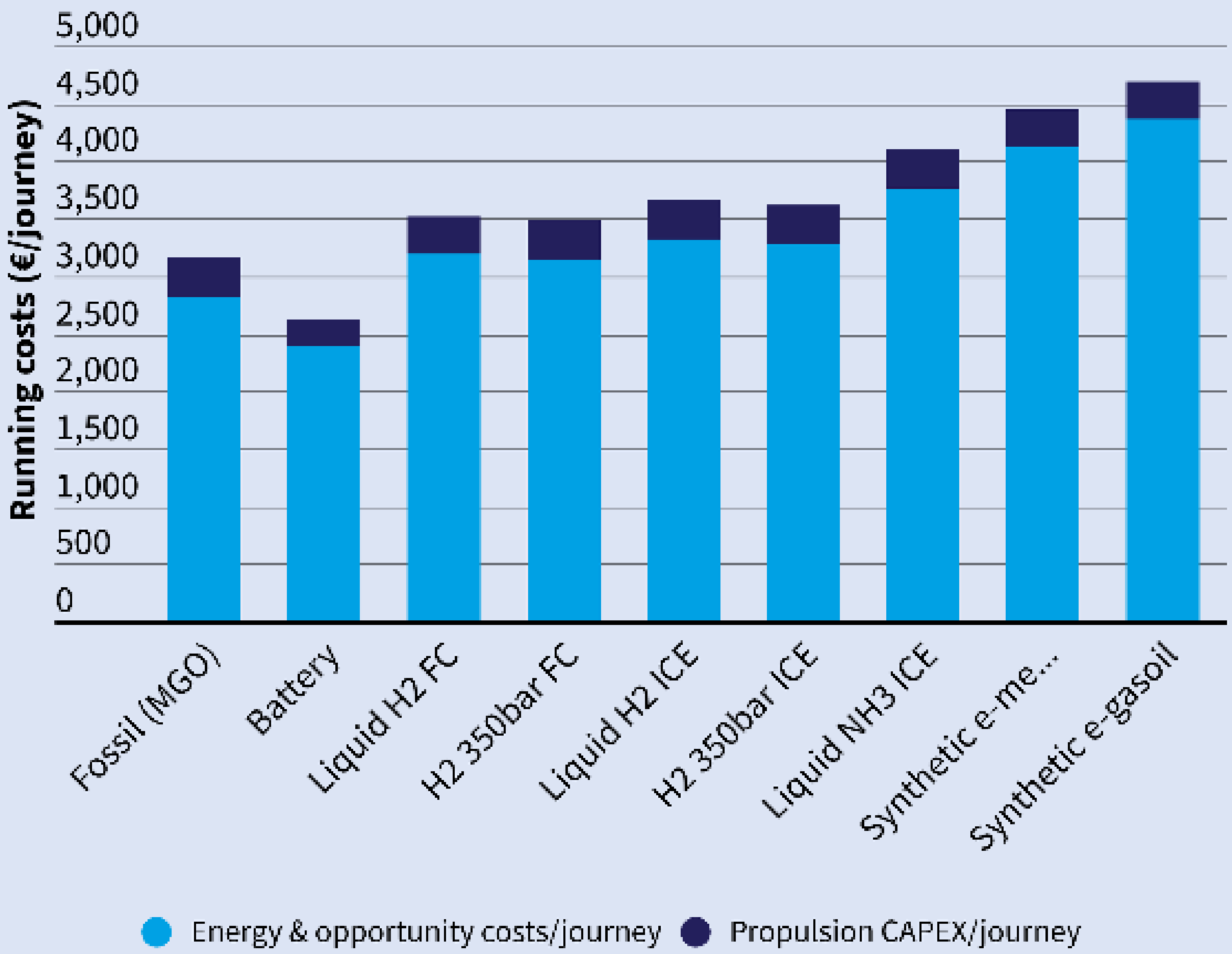
Electricity prices ranging from 0.1€/kWh in 2018 to 0.07 in 2050.
Electrolysis efficiency ranging from 65% in 2018 to 77% in 2050
Syntheses efficiencies: NH3 - 88%, CH4 - 77%, e-Gasoil-73%.

Source: Chris Mallins analysis for T&E, 2019.

Zero Emission Calais - Dover ferry | Today



Zero Emission Calais - Dover ferry | Future



Synthetic methane & gasoil

✓ **Technical feasibility**

✓ **Climate benefits** (without environmental degradation)

✓ **Sustainably scalable**

✗ **Responsible consumption**

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✗ **Enforceability**

Batteries, Hydrogen & Ammonia

✓ **Technical feasibility**

✓ **Climate benefits** (without environmental degradation)

✓ **Sustainably scalable**

✓ **Responsible consumption**

✓ **‘Primus inter pares’** (*cheapest* among the equals)

✓ **Enforceability**

Key takeaways

Key messages

- **Invest in shore-side electricity (SSE) – no regret option**
  - Make use of SSE mandatory under AFID
  - Exempt SSE from taxes or tax HFO/MGO/LNG
- **LNG infrastructure will lead to stranded assets**
  - Discontinue the LNG mandate under AFID
- **Invest in zero-emission fuel supply infrastructure in ports**
- **Tighten air emissions standards, e.g.:**
  - Zero emission berth/port standard
  - Zero emission green lanes *(bilateral ports?)*
  - Routes under public service obligations (PSO) *(already subsidised why not green?)*

Merci!

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Air pollution: CNG/LNG in road transport

Vehicle	Comparison	Carbon dioxide (CO_2)	Nitrogen oxides (NO_x)	Particulate matter (PM)
Metric		WTW emissions	Emissions reduction for a 5% NGV share	Emissions reduction for a 5% NGV share
Petrol car	CNG	-18%	0%	-4.0%
Diesel car	CNG	+6%	-3.5%	-4.5%
Van	CNG	+8%	-3.6%	-4.0%
Small rigid truck	CNG	+13%	0%	-4.5%
Large rigid truck 26t	LNG	+16%	0%	-3.2%
Articulated truck >32t	LNG	+2%	0%	-1.8%
Coach	LNG	+15%	0%	-4.4%
Bus	LNG	+6%	0%	-5.4%

Source: Ricardo Energy & Environment, 2016

Investment test

	Reduces air pollution (SOx, NOx, PM)	Investment required in ship technology (new build or retrofits)	Investment required in new shore-side bunkering infrastructure
LNG	yes	yes	yes
MGO (0.1% S) + SCR + DPF	yes	yes	no