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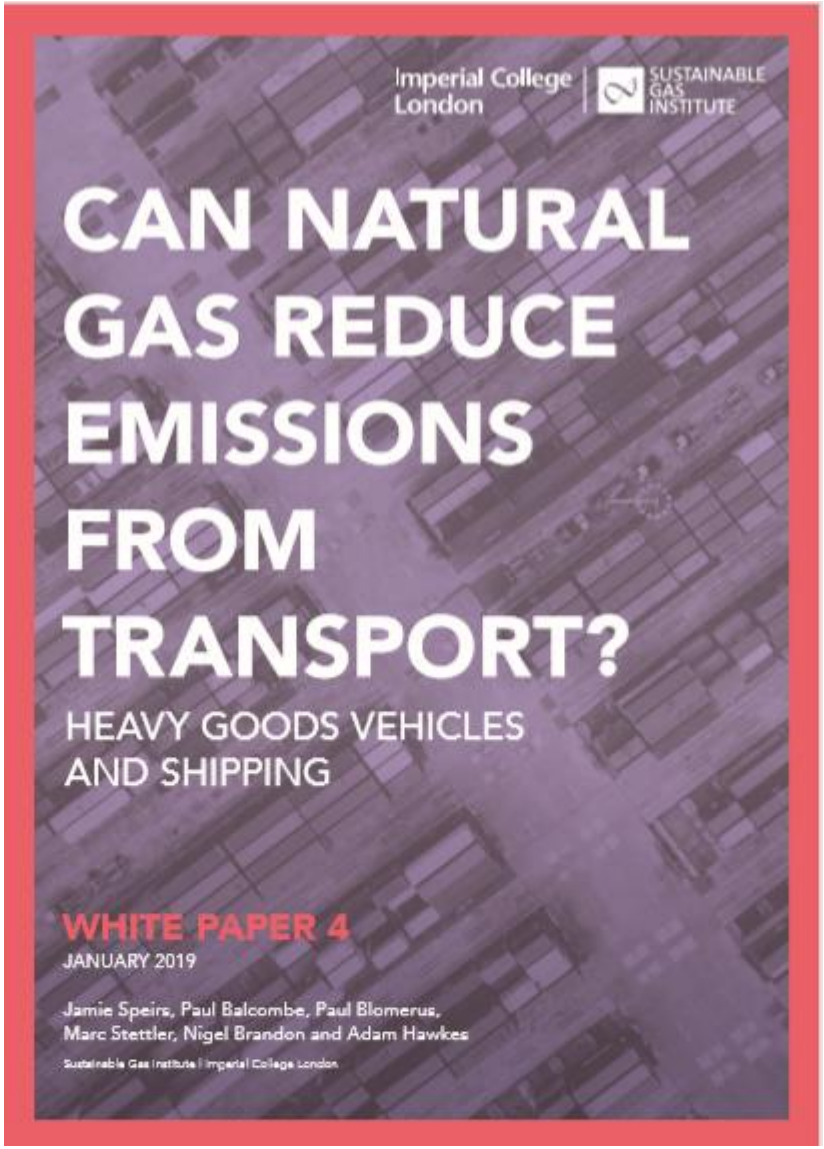

Can natural gas reduce emissions from trucks and ships?

28th January 2019

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  - A systematic review of the **contemporary evidence base** and **primary analysis** to fill gaps in current knowledge.
  - Each paper begins with a published **scoping note** and reviewed by an **international expert panel** to provide guidance and advice.
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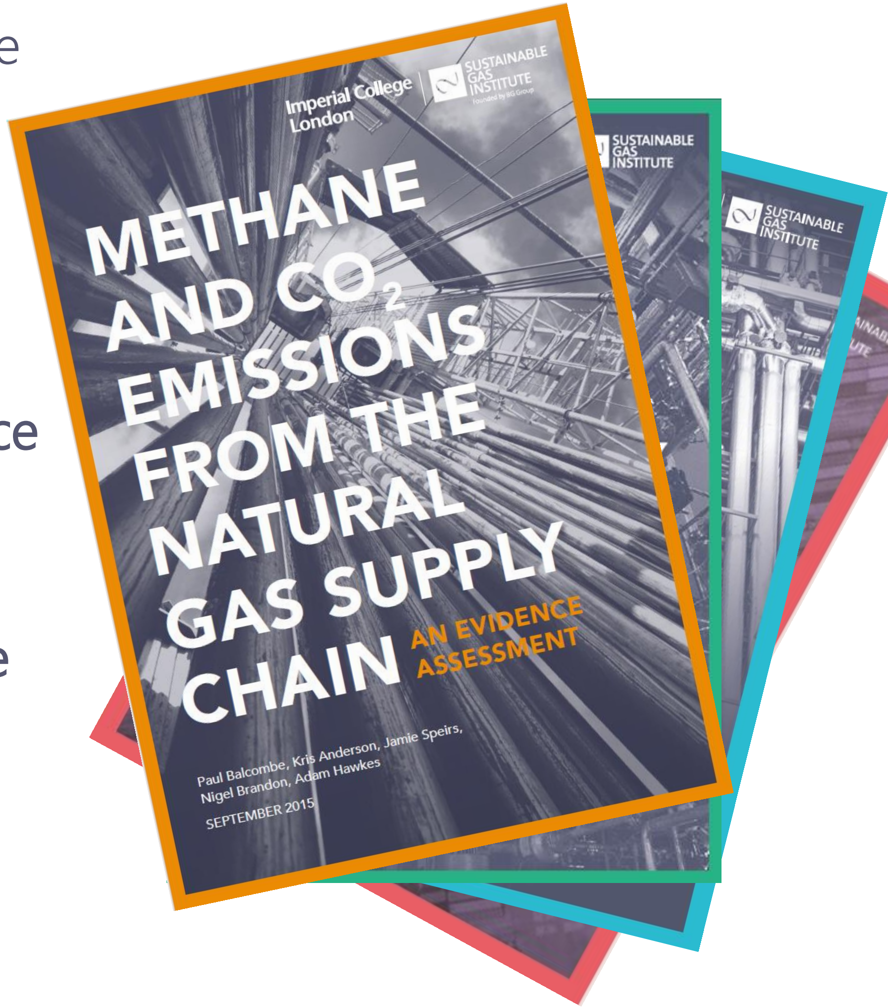

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The Challenge

- International **shipping and road freight** contribute ~10% to global CO_2 emissions
- Demand for both services is growing – leading to growing emissions
- Both under increasing pressure to reduce emissions:
  - International Maritime Organisation 50% ship fleet GHG reduction by 2050
  - EU 30% new truck fleet CO_2 reduction by 2030

<u>But</u>

- Difficult to decarbonise due to significant range and load requirements
- Very difficult to address without increasing costs
- Battery electric or hydrogen fuel cell options challenging with current technology

Natural gas solution?

- Natural gas may be used as a transport fuel in both ships and trucks may:
  - deliver **greenhouse gas** emissions reduction against existing ships and trucks
  - provide benefits in **air pollutants** such as NO_X, SO_X and particulates
  - be **relatively cheap** and are currently available

<u>However</u>

- There is disagreement as to the magnitude of benefit that natural gas can deliver
- The nature of the GHG challenge means it is important to understand this role

Context: The CO_2 intensity of fuel

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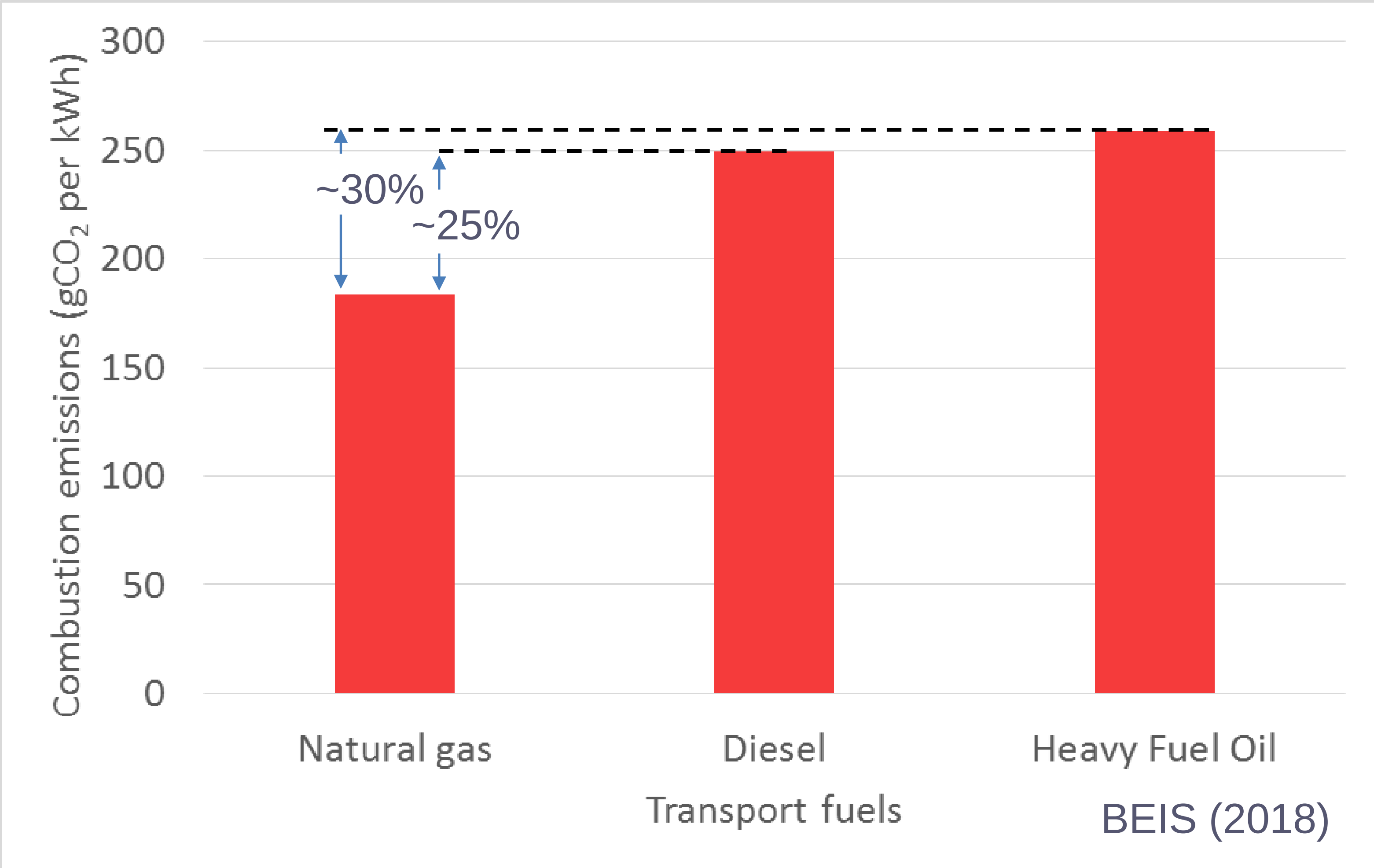
- Natural gas is:
  - ~25% less carbon intensive than **diesel**
  - ~30% less carbon intensive than **heavy fuel oil (HFO)**



BEIS (2018)

Context: Natural gas supply chain

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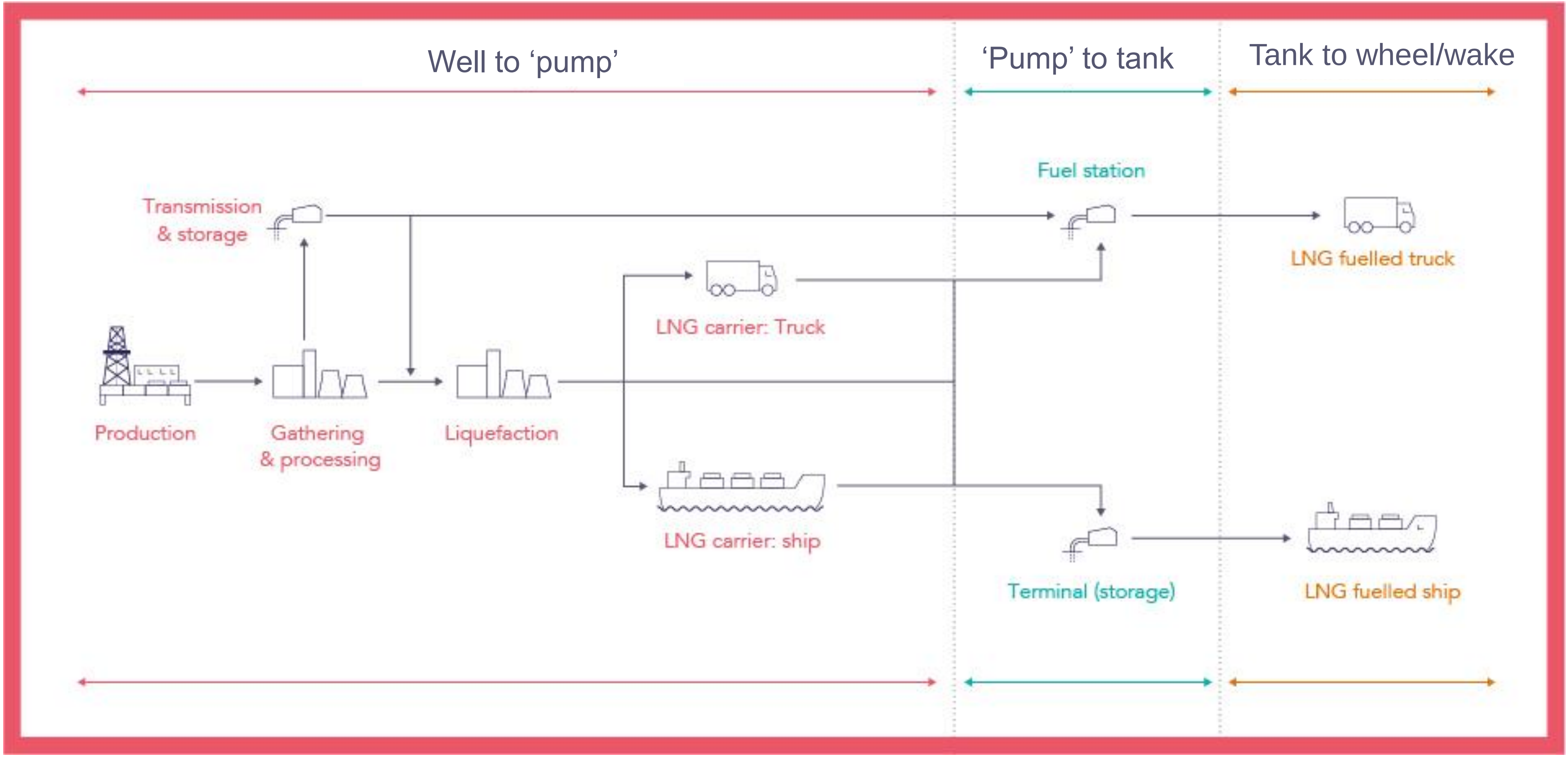
Emissions throughout the supply chain reduce the benefit of natural gas

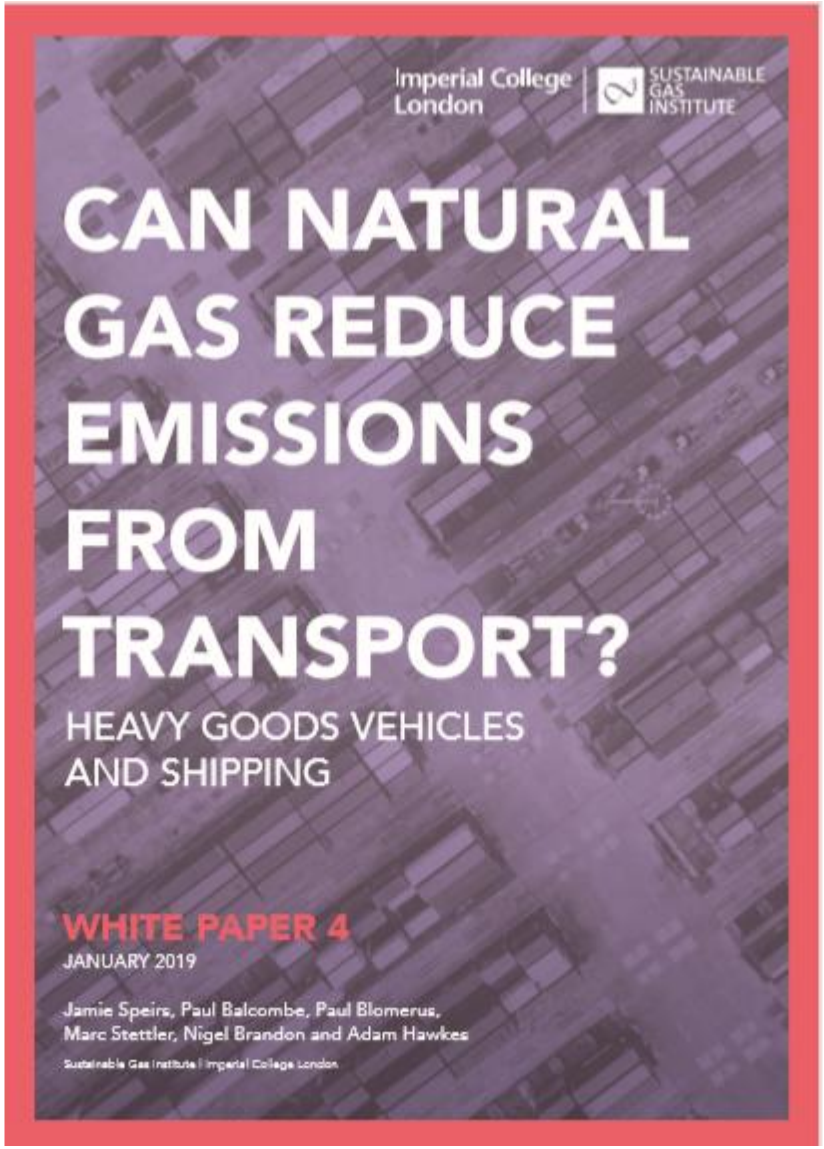
- Efficiency deficit in natural gas engines
- Methane (CH_4) slip in exhaust gas
- Supply chain emissions of CO_2 and CH_4

CH_4 GWP100 = 34



Aims and scope

- Conduct a systematic review to answer:
- How much can natural gas contribute to emissions reduction in trucks and ships?
    - GHG reduction potential
    - Air pollution reduction potential
    - Costs
- Examining the full supply chain.



Evidence Review Methodology

	Scope the project	Solicit expert input	Review the literature	Synthesis and analysis	Prepare the draft report	Expert panel review and refine	Publish and promote
TASKS	• Write a scoping note, outlining aims and search and review protocols	• Appoint expert panel • Solicit expert panel comments on scoping note • Finalise aims and search and review protocols	• Apply protocol to literature search • Detailed and transparent 'trawl' • Identify relevant sources	• Apply protocol for evaluation and synthesis of literature	• Write preliminary draft report	• Solicit expert panel comments on draft report • Revise draft report	• Design and format report • Publish and publicise report • Launch event
OUTPUT	• Submit scoping note to expert panel						Publish report

Systematic Review of Literature

- Systematic
- Replicable
- Robust

Expert Panel

- Wide Range of experts
- Academia, industry, government, third sector
- Provide guidance on scope
- Provide review of emerging analysis

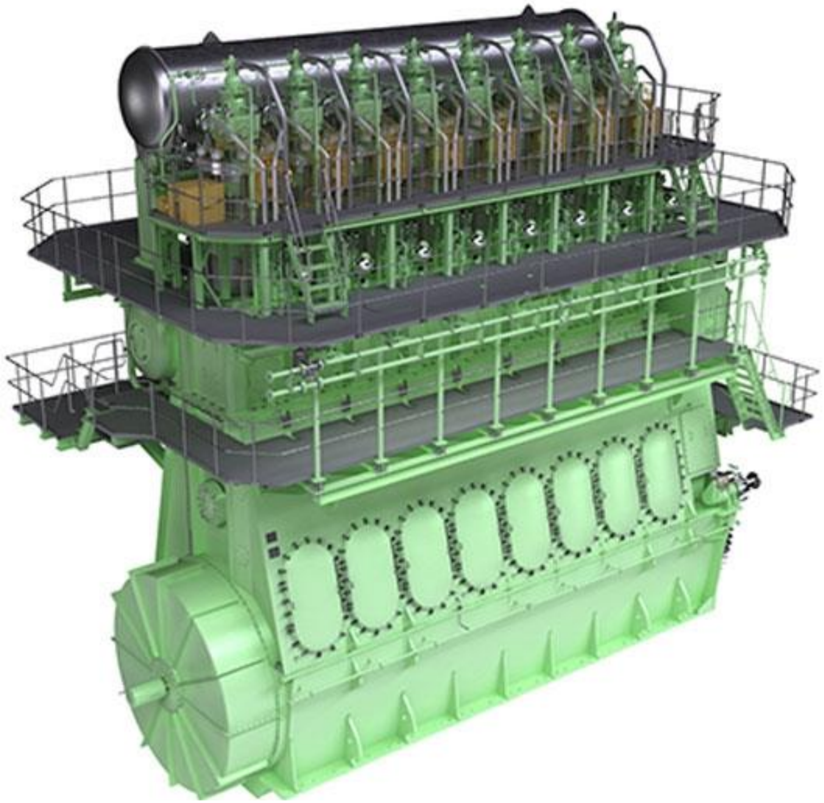
Final Report

- Analysis of evidence
- Accessible, written for non-expert audience

Natural gas engines

Broadly two approaches to natural gas engines:

- Spark ignition using only gas
- Compression ignition, using both gas and diesel pilot fuel



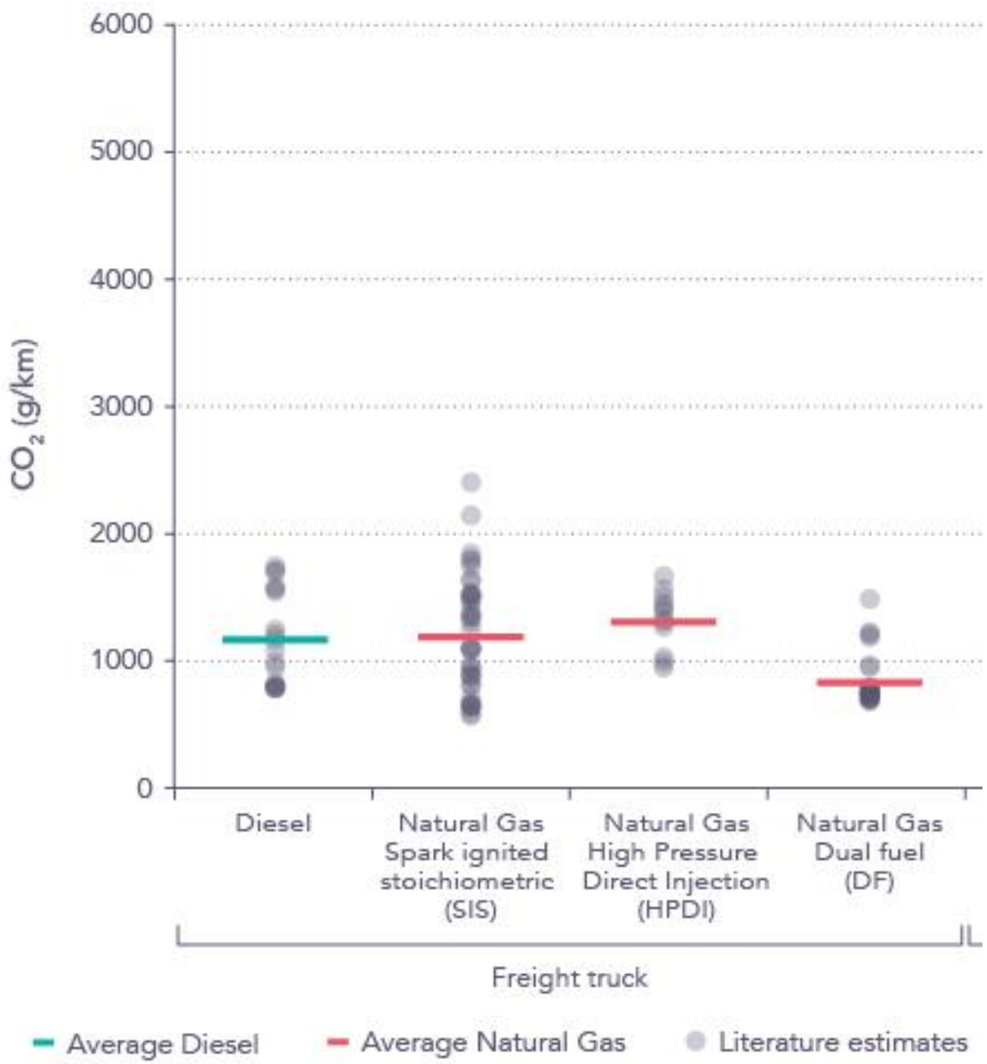
Truck engines	
SILB	Spark ignited lean-burn
SIS	Spark ignited stoichiometric
DF	Dual fuel
HPDI	High pressure direct injection

Ship engines	
LBSI	Lean burn spark ignited
MS-LPDF	Medium speed low pressure dual fuel
LS-LPDF	Low-speed low pressure dual fuel
LS-HPDF	Low-speed high pressure dual fuel

Greenhouse gas emissions from natural gas trucks

Truck CO_2 emissions

- Ranges of estimates driven by estimation method
- **Worst** case shows emissions increase
- **Best** case shows emissions reduction though less than fuel potential due to efficiency difference between natural gas and diesel engines

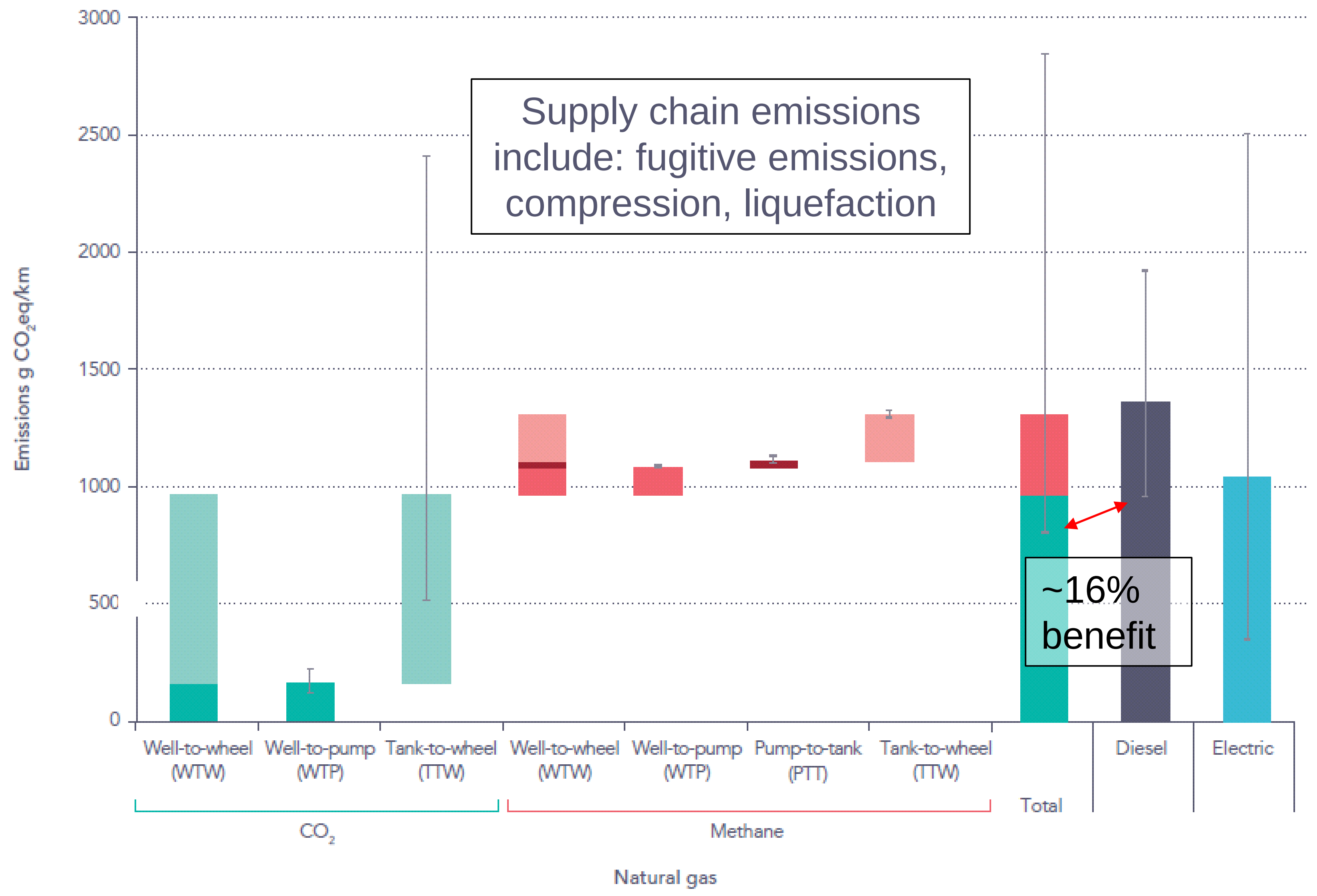


Truck methane emissions

- Methane emissions can be significant if not controlled
- This creates significant CO_2 equivalent emissions
- Best engines on optimal test cycles already meet EURO VI emissions limit (0.5g/kWh)

Truck Well to Wheel GHG emission

- **~16% GHG** benefit measuring best against best
- Majority of GHGs are CO_2 and tank to wheel
- Methane slip contributes about ~15% to total emissions
- Supply chain methane increases this to ~26%



Greenhouse gas emissions from natural gas ships

Ship CO_2 emissions

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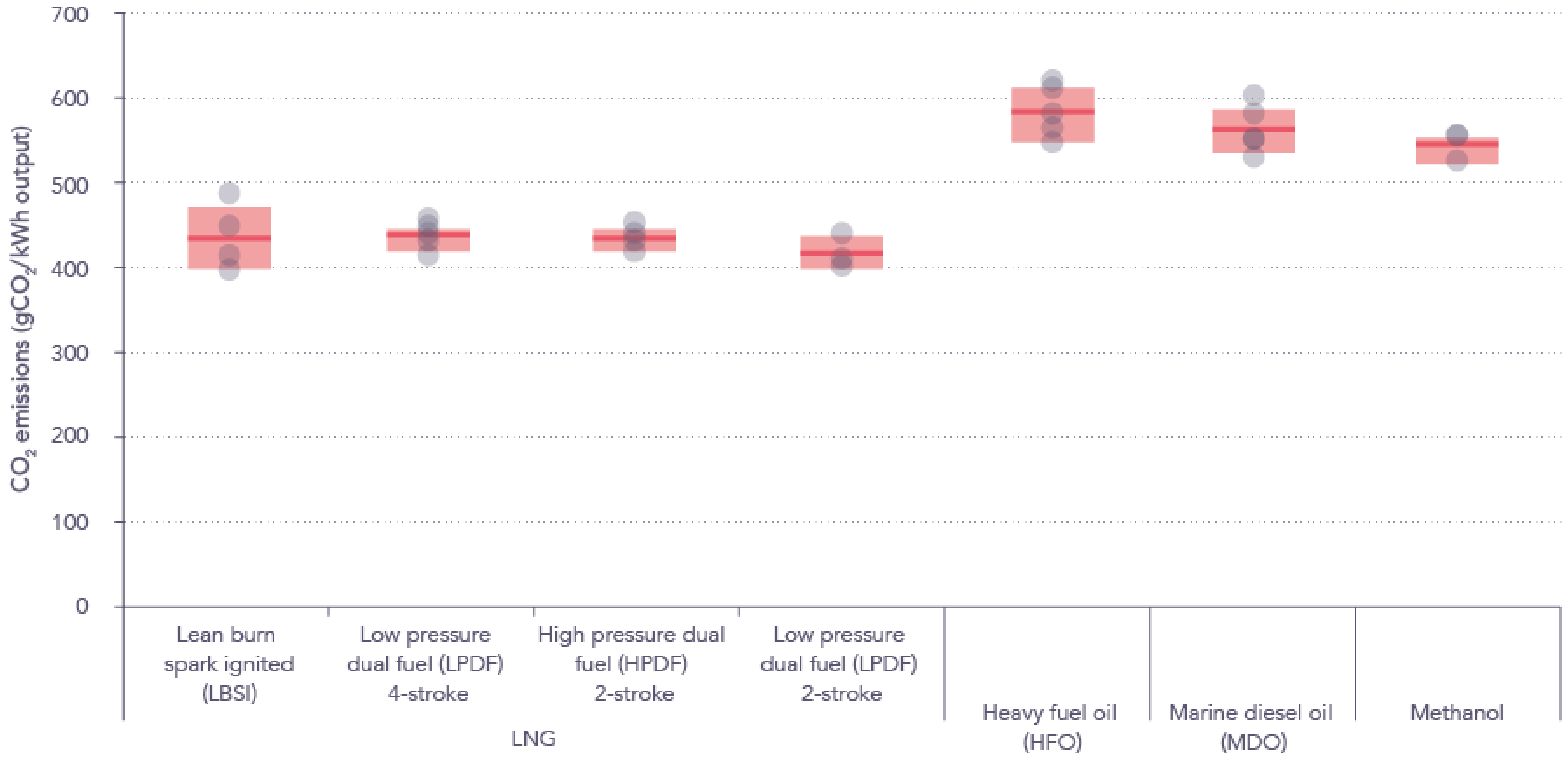
- CO_2 emissions from natural gas broadly similar
- Close to expected emissions reduction (~28%)



Ship methane emissions

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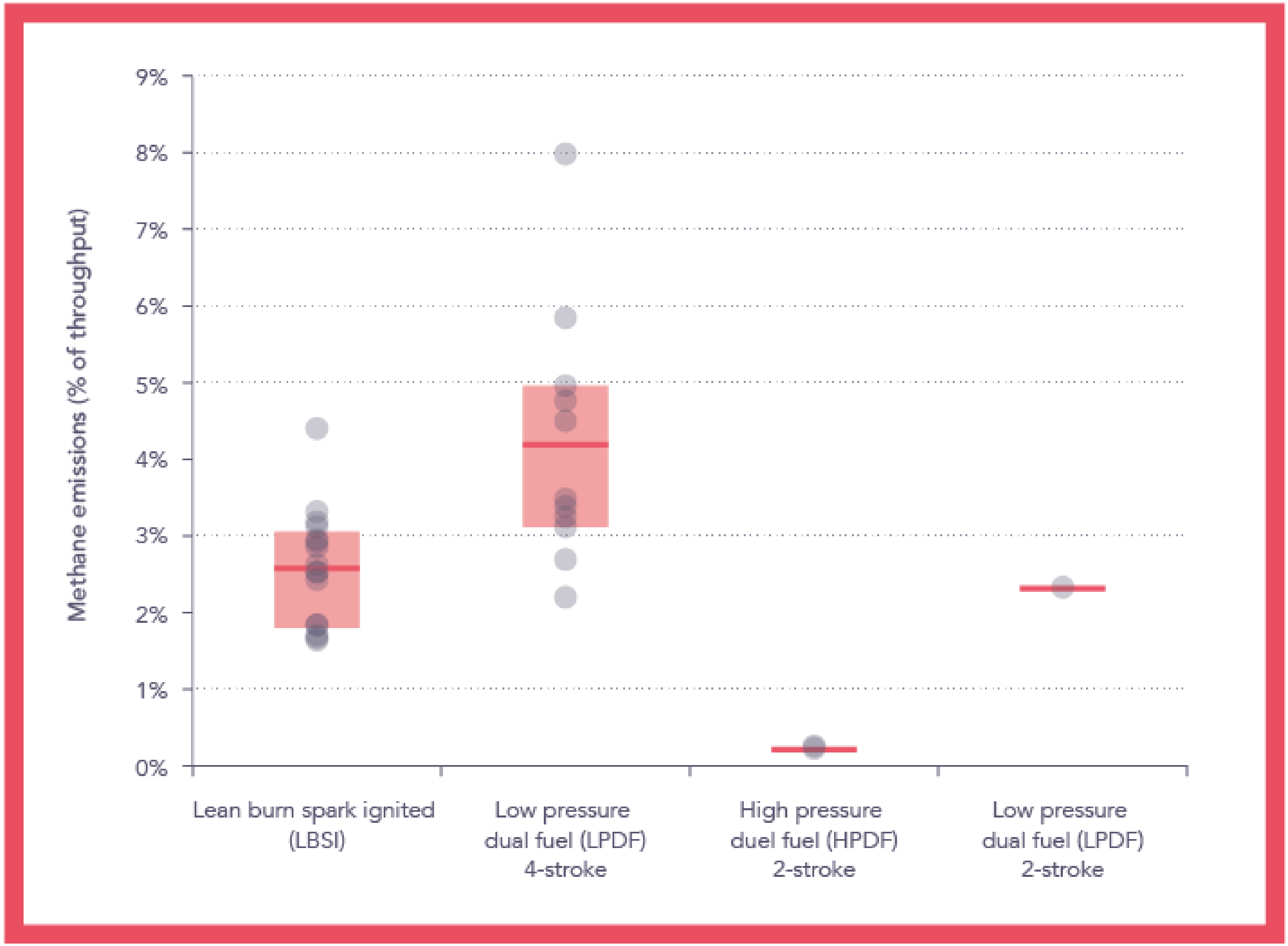
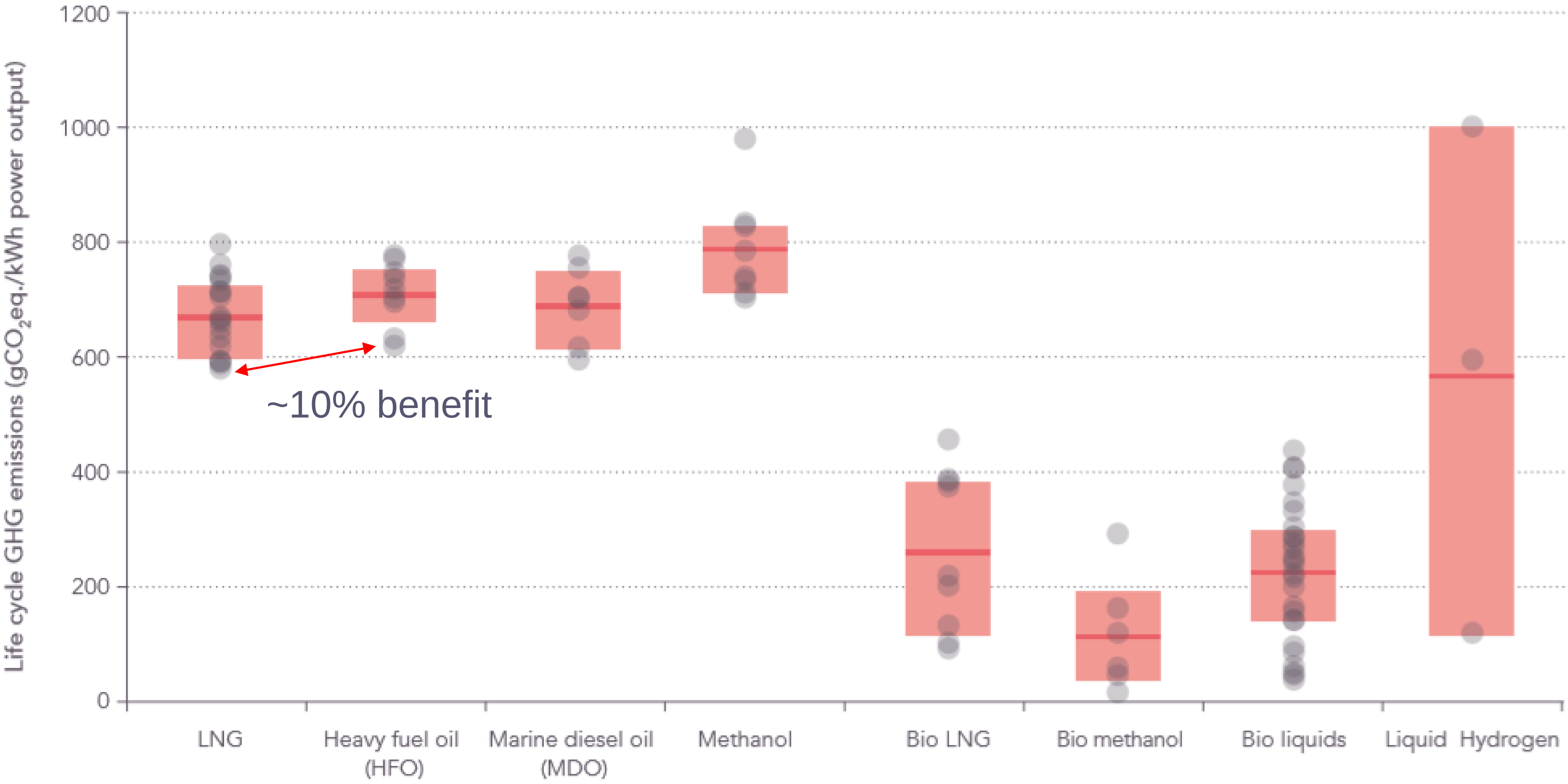
- Methane slip can be significant in ships.
- High pressure dual fuel engines perform best, though more estimates needed



Ship Well to Wake GHG emission



Ship Well to Wake GHG emission

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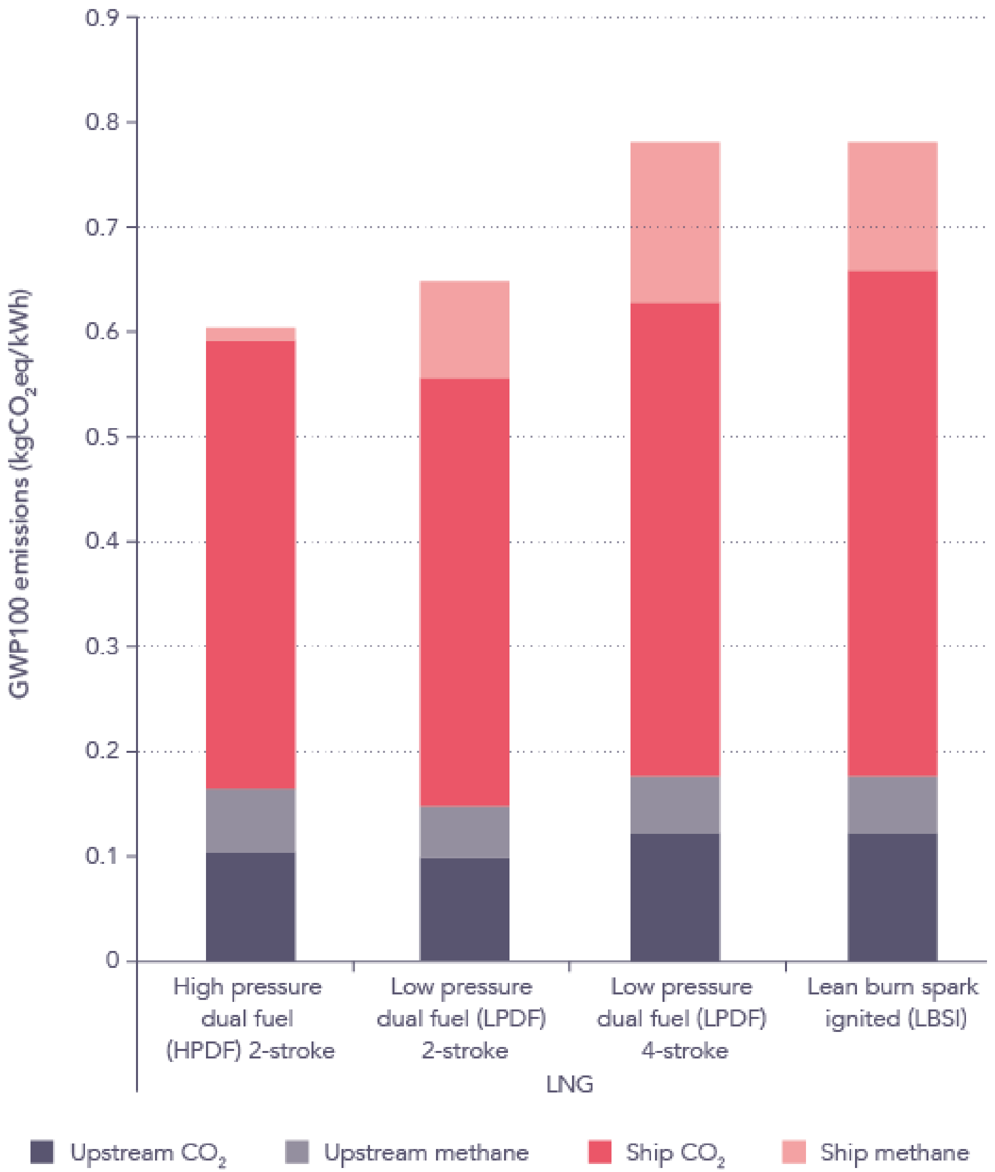
- Methane slip contributes as little as ~2% and as much as ~20%
- Supply chain contributes ~23% to ~27%

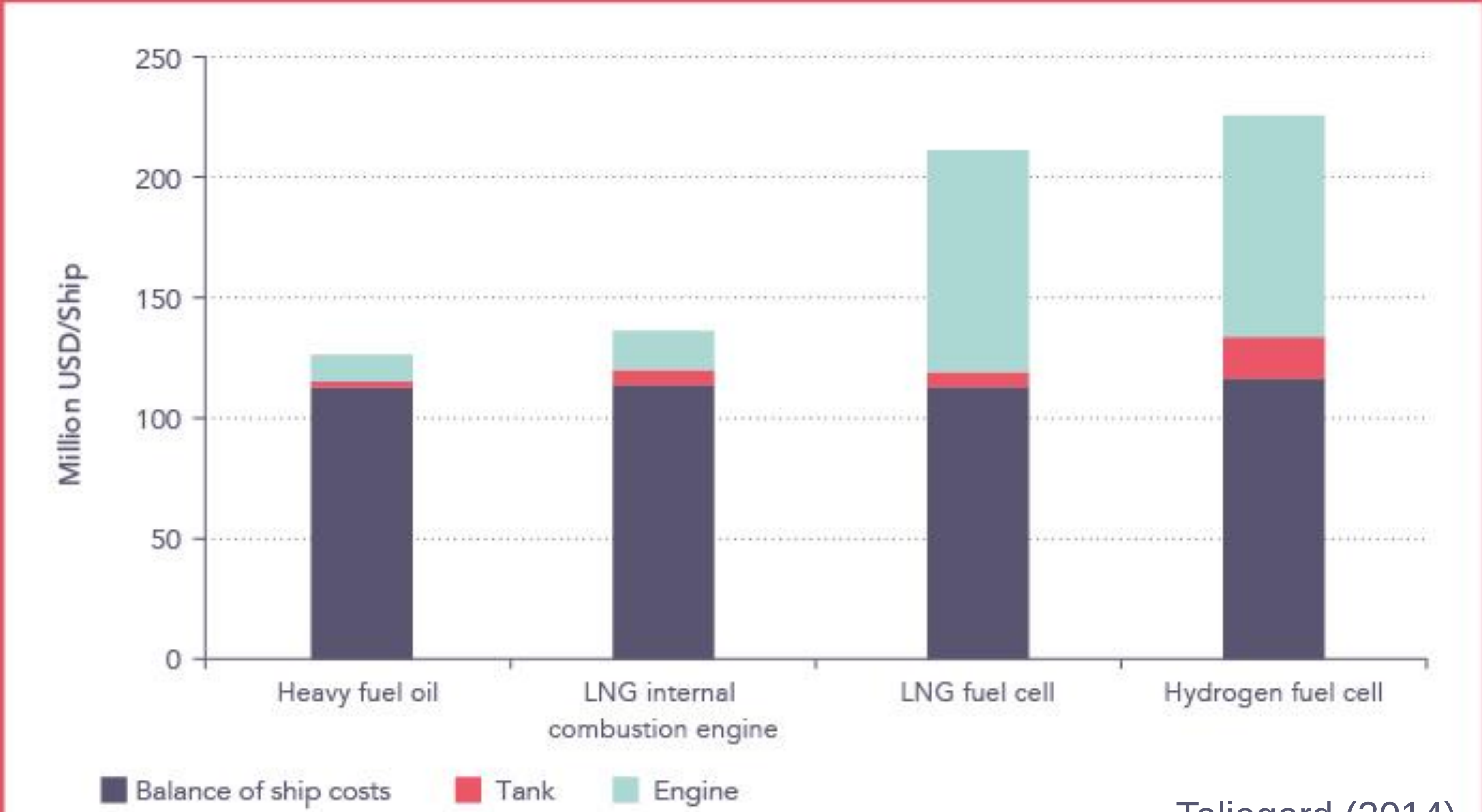


Costs of natural gas trucks and ships

Capital costs → Fuel costs → Total Cost of Ownership

Costs: Natural gas ships

- Heavy fuel oil ships less expensive than LNG ships – tank and engine costs
- Advanced engines such as fuel cells may be significantly more expensive



Taljegard (2014)

Costs: Natural gas ship fuels

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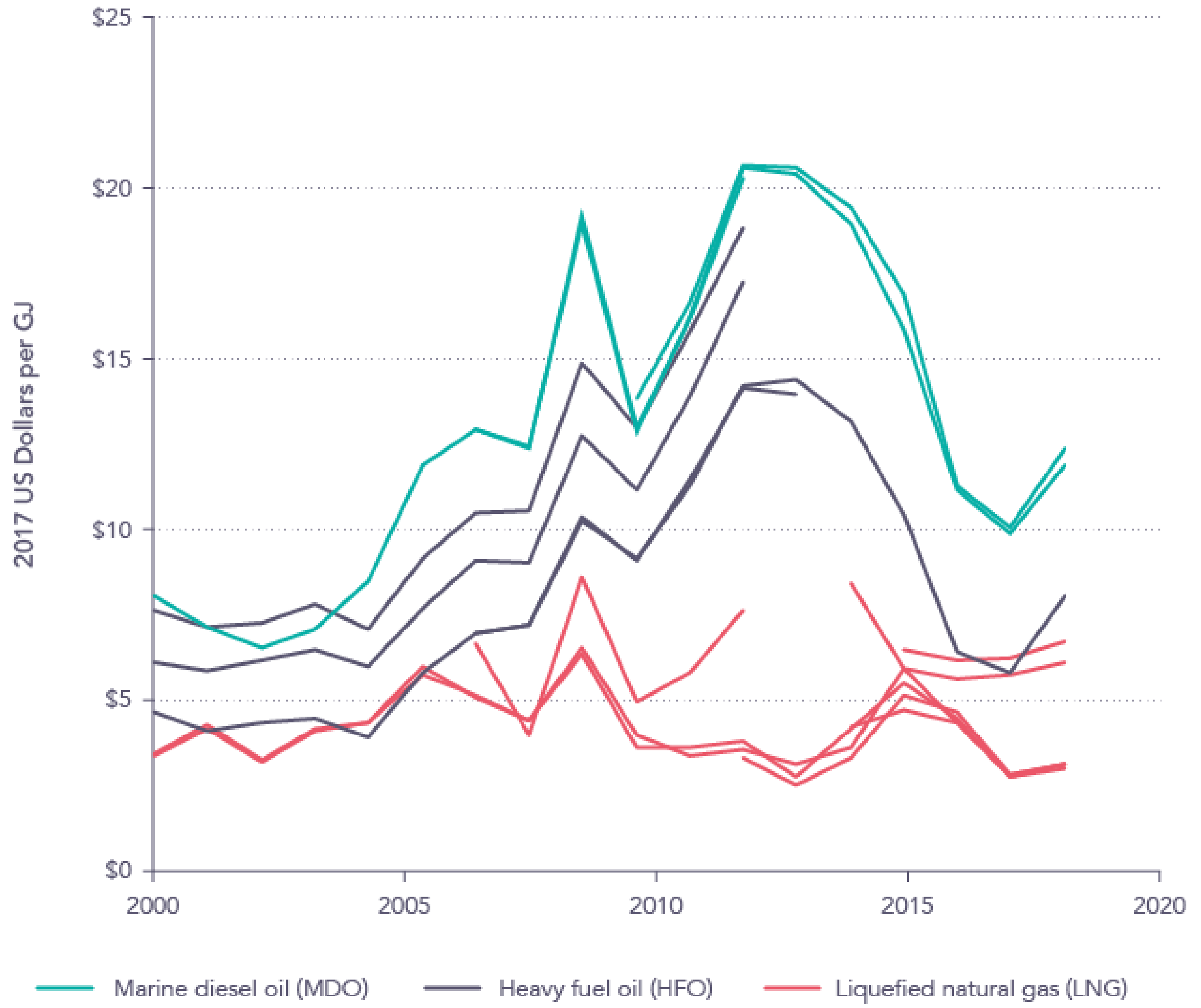
- LNG appears to be cheaper than heavy fuel oil or marine diesel oil
- Bunkering costs expected to be small
- This provides a cost benefit that may “pay back” the extra investment in LNG ships



Total cost of ownership: ships

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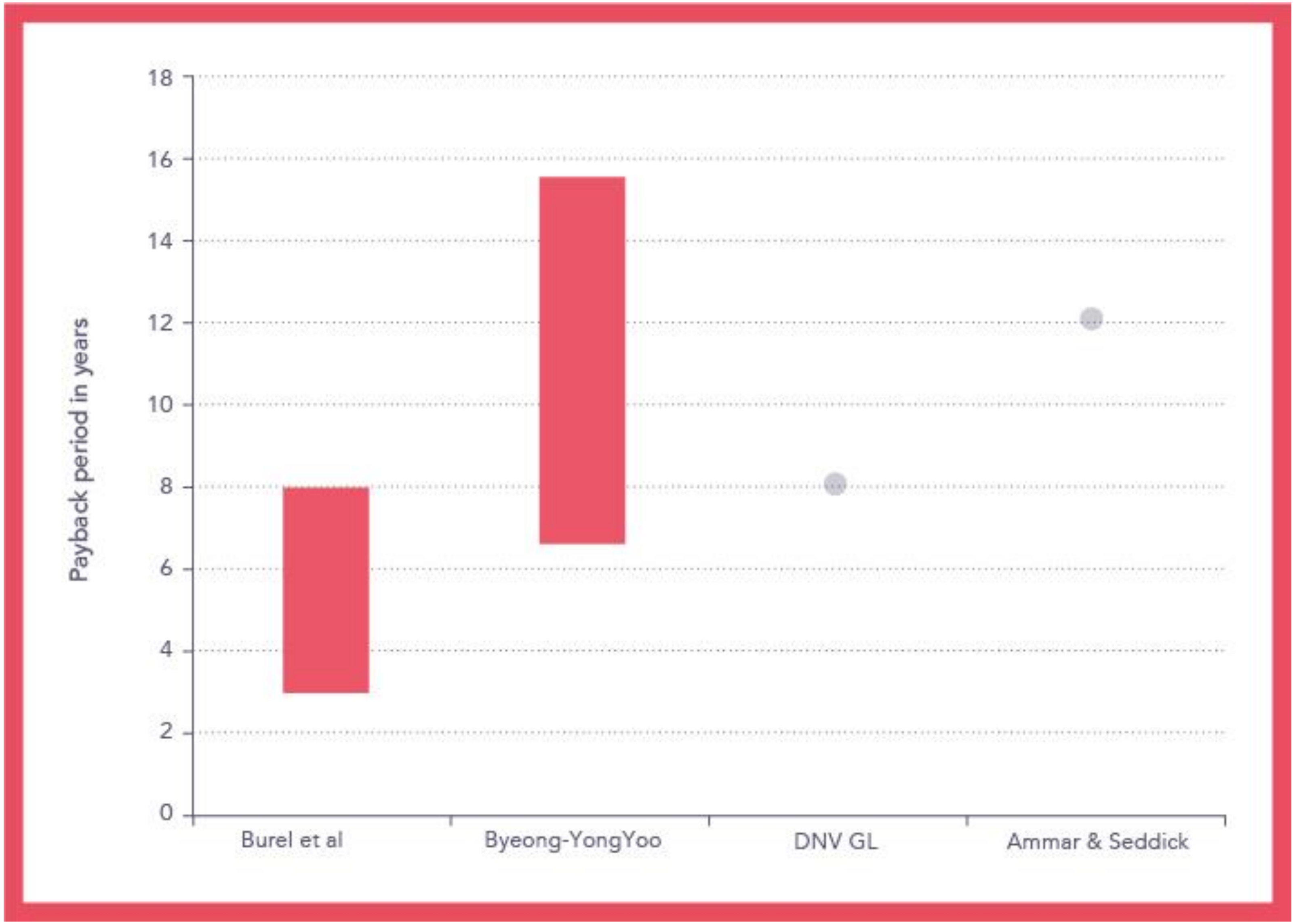
Estimated payback periods vary, driven by:

- Fuel prices
- Vessel costs
- Annual distance

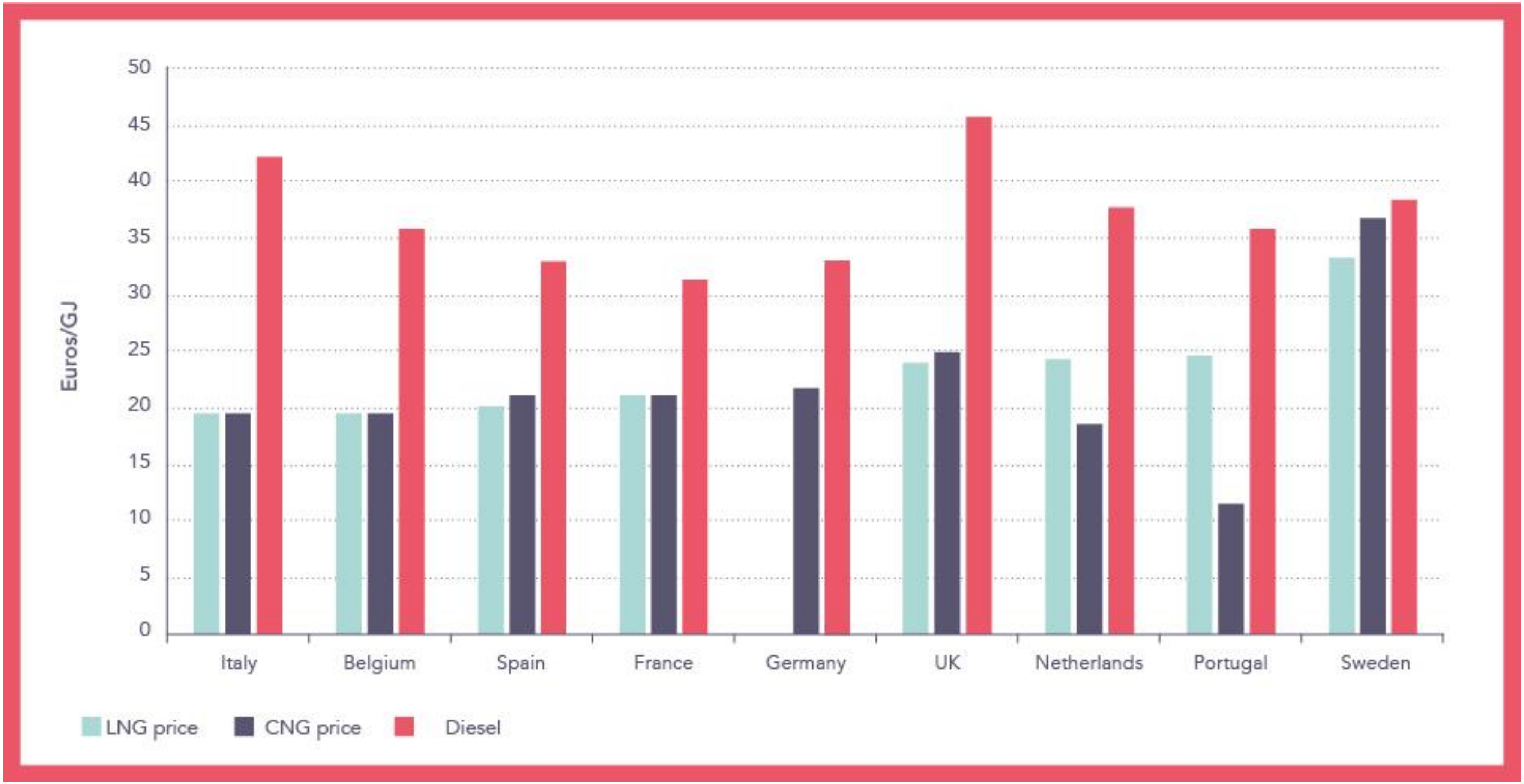
- As assumed fuel price difference decreases, estimated payback period increases

- However, central assumptions in most studies lead to suitable payback period



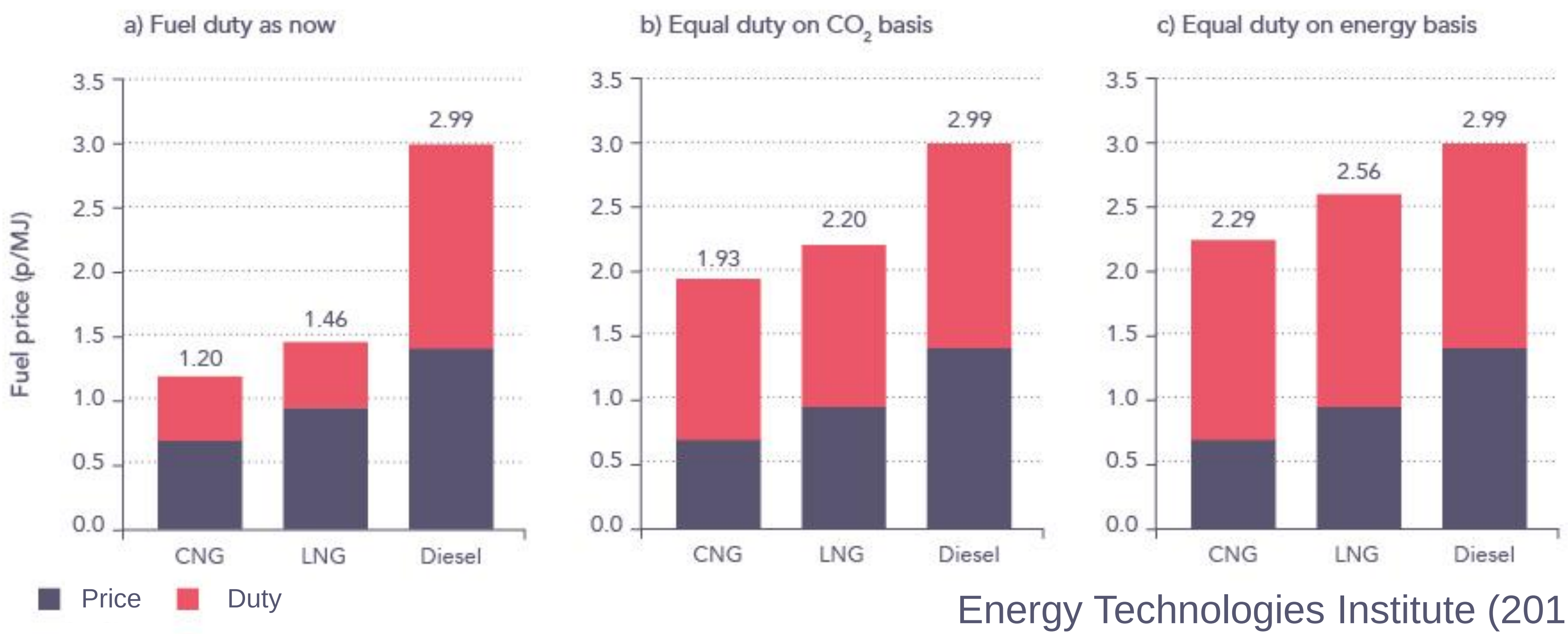
Truck fuel costs in Europe

- Story very similar in truck costs. Diesel trucks cheaper than natural gas
- Natural gas fuel also cheaper than diesel at the forecourt
- However, parity pricing in CNG and LNG in some countries might not reflect costs



Fuel cost and duty: trucks

- Fuel duty currently favours natural gas transport fuels
- However, that may not continue in the future
- If fuels are taxed equally on a CO_2 or energy basis natural gas may still be cheaper



Energy Technologies Institute (2018)

Air Pollution

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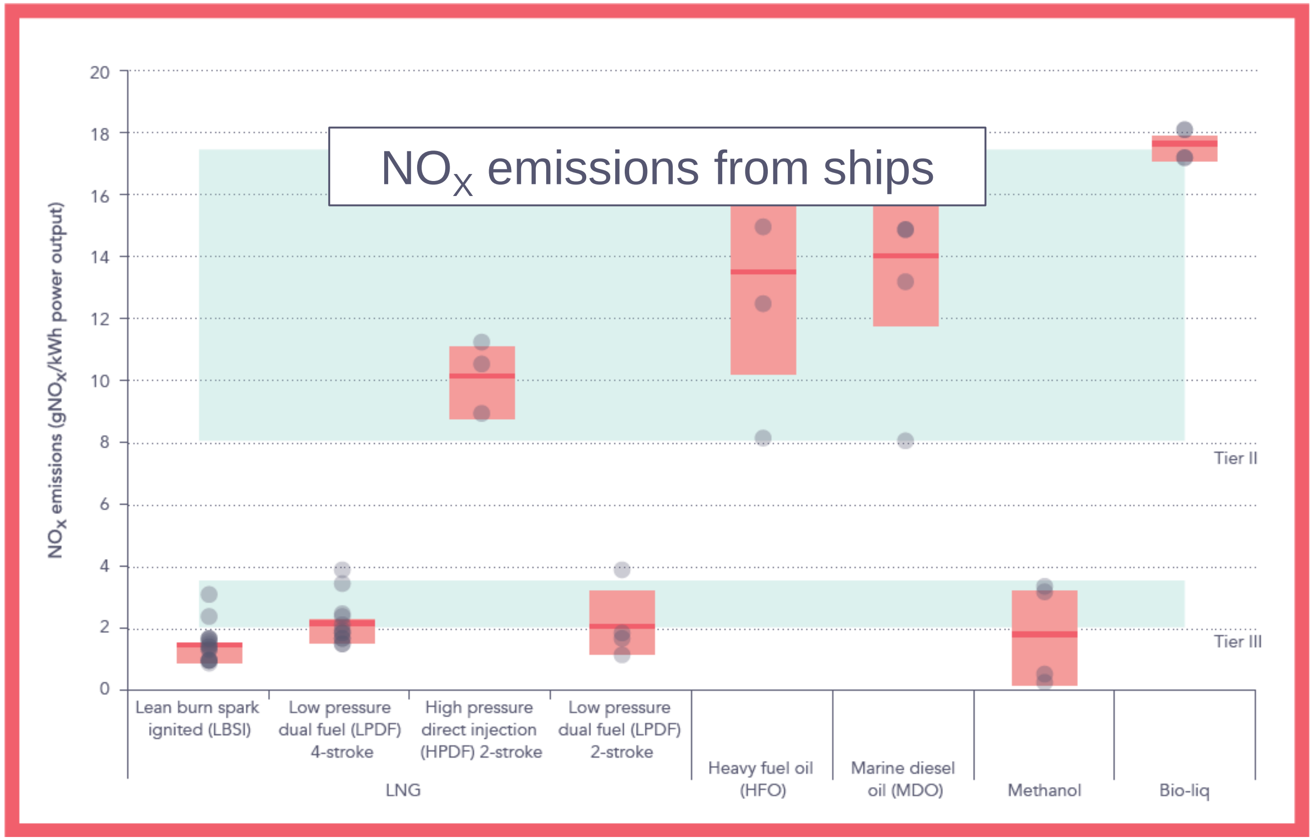
- Air pollution in ships can be reduced by a switch to natural gas as a fuel
  - NO_X reduced by ~90%, SO_X reduced by 90% and PM reduced by 98%

- Improvements in diesel trucks have reduced the relative benefit of natural gas to reduce air pollution

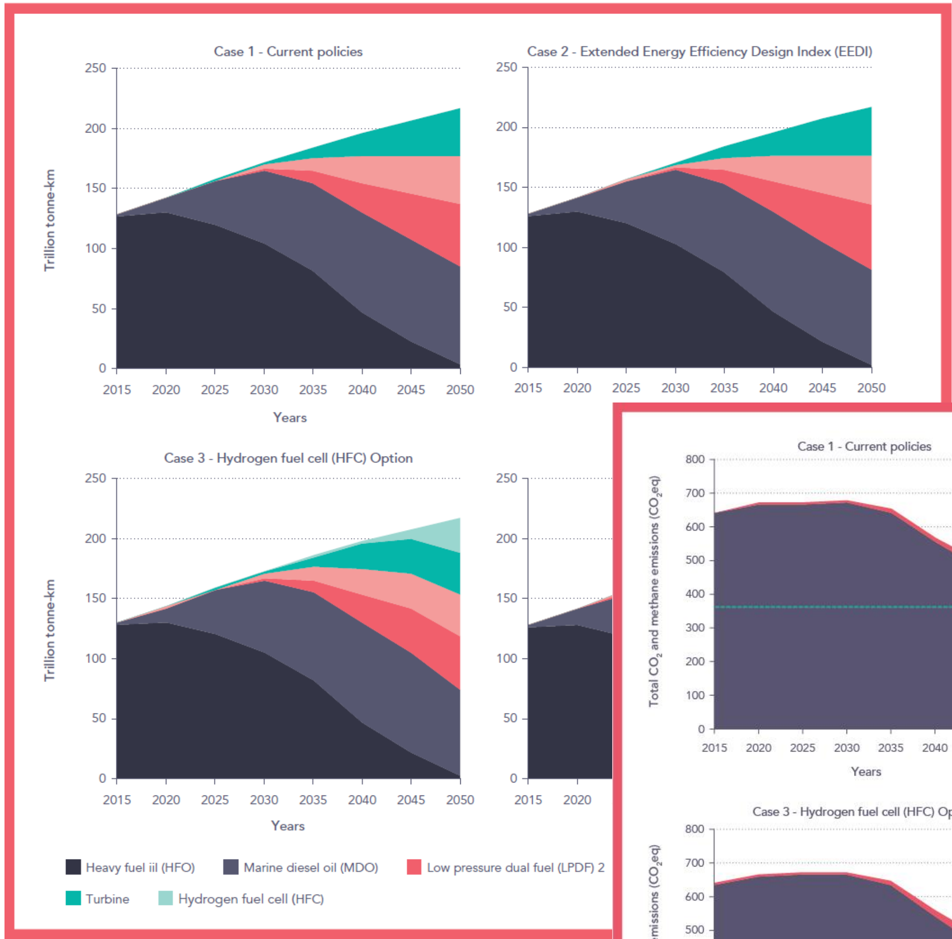
- While improvements are still found in motorway driving cycles, urban driving cycles are likely to result in reduced benefits

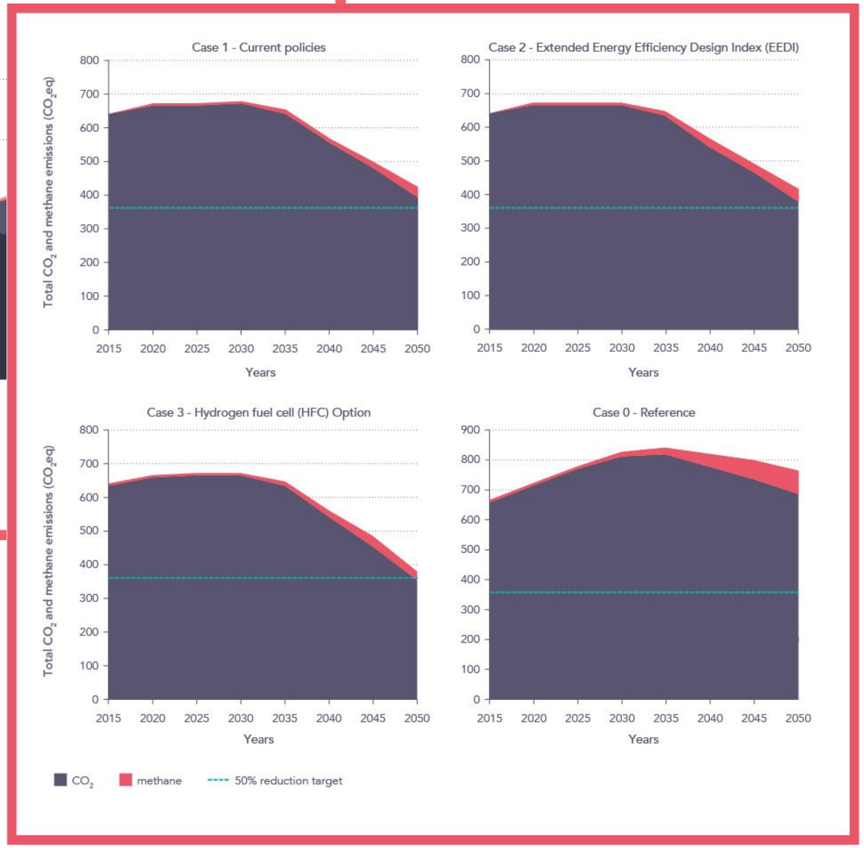


MUSE ship fleet model

Whole system modelling of shipping

- Challenging to meet 50% GHG reduction target with natural gas, even including lots of energy efficiency
- Need for wider set of options including efficiency measures and low carbon technology
- Without broader efficiency measures and low emissions ships emissions are likely to increase





muse

Key Findings

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The benefits of natural gas as a fuel

- Greenhouse gas emissions may be reduced by **~16%** for trucks and **~10%** for ships
- Air pollution may also be reduced - significant for ships, but more nuanced for trucks
- May be cost competitive with existing fuels and engines

However

- Natural gas will not be sufficient to meet low carbon targets such as IMO

The Uncertainties

- Range of estimates with worst case emissions of both GHGs and air pollution can be worse than diesel trucks and HFO ships
- Cost benefit reliant on favourable tax and current fuel price

Remaining questions?

- How to ensure that natural gas delivers greatest benefit possible
- How to develop understanding and mitigation of emissions throughout life cycle
- How to ensure development of next generation, lower emissions technologies
- How to address the issues of lock-in with long vehicle or vessel lifetime

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Thank you for your attention

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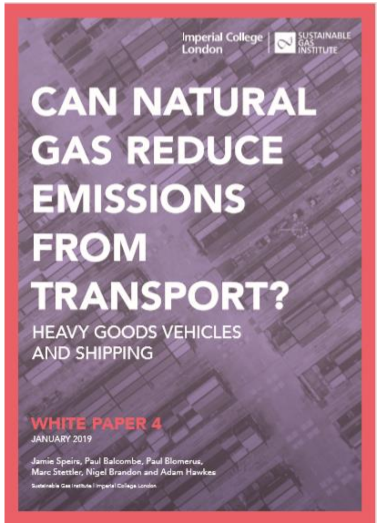

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https://www.sustainablegasinstitute.org/can-natural-gas-reduce-emissions-from-transport/

Back-up slides