Can natural gas reduce emissions from trucks and ships?

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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.

  • Published **online** with a short two-page briefing note.

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The Challenge

• International **shipping and road freight** contribute ~10% to global CO₂ 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 CO₂ reduction by 2030

But

• 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

However

- 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 CO₂ intensity of fuel

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

![Graph showing CO₂ emissions for different fuels.]

BEIS (2018)
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

**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

### Evidence Review Methodology Table

<table>
<thead>
<tr>
<th>Scope the project</th>
<th>Solicit expert input</th>
<th>Review the literature</th>
<th>Synthesis and analysis</th>
<th>Prepare the draft report</th>
<th>Expert panel review and refine</th>
<th>Publish and promote</th>
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<tbody>
<tr>
<td>TASKS</td>
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<tr>
<td>Write a scoping note, outlining aims and search and review protocols</td>
<td>Appoint expert panel</td>
<td>Apply protocol to literature search</td>
<td>Apply protocol for evaluation and synthesis of literature</td>
<td>Write preliminary draft report</td>
<td>Solicit expert panel comments on draft report</td>
<td>Design and format report</td>
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<tr>
<td></td>
<td>Solicit expert panel comments on scoping note</td>
<td>Detailed and transparent ‘brief’</td>
<td>Identify relevant sources</td>
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<td>Publish and publicise report</td>
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<tr>
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<td>Finalise aims and search and review protocols</td>
<td></td>
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<td>Launch event</td>
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OUTPUT
- Submit scoping note to expert panel
Natural gas engines

Broadly two approaches to natural gas engines:

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

<table>
<thead>
<tr>
<th>Truck engines</th>
<th>Ship engines</th>
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</thead>
<tbody>
<tr>
<td>SILB</td>
<td>LBSI: Lean burn spark ignited</td>
</tr>
<tr>
<td>SIS</td>
<td>MS-LPDF: Medium speed low pressure dual fuel</td>
</tr>
<tr>
<td>DF</td>
<td>LS-LPDF: Low-speed low pressure dual fuel</td>
</tr>
<tr>
<td>HPDI</td>
<td>LS-HPDF: Low-speed high pressure dual fuel</td>
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</table>
Greenhouse gas emissions from natural gas trucks
Truck CO₂ 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)
~16% GHG benefit measuring best against best

Majority of GHGs are CO₂ and tank to wheel

Methane slip contributes about ~15% to total emissions

Supply chain methane increases this to ~26%

Supply chain emissions include: fugitive emissions, compression, liquefaction

~16% benefit
Greenhouse gas emissions from natural gas ships
Ship CO$_2$ emissions

- CO$_2$ emissions from natural gas broadly similar
- Close to expected emissions reduction (~28%)
Ship methane emissions

- Methane slip can be significant in ships.
- High pressure dual fuel engines perform best, though more estimates needed.
Ship Well to Wake GHG emission

~10% benefit
• 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
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
Costs: Natural gas ship fuels

- 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

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
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
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
Key Findings

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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Download the full White Paper and the Briefing Note at:

https://www.sustainable gas institute.org/can-natural-gas-reduce-emissions-from-transport/
Back-up slides