



White Paper 4

Gas in Transport: Heavy Goods and Shipping

Scoping Note
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1. Introduction

The Sustainable Gas Institute (SGI) at Imperial College London was created with the mission to understand the role of gas in a low carbon future. The SGI White Paper Series contributes to this mission, providing globally impactful, policy facing analysis and bringing clarity to contentious topics in the energy sector. This is delivered through the use of Systematic Review of the contemporary evidence base, expert elicitation and primary analysis to fill gaps in current knowledge.

Each project in the SGI White Paper Series begins with a published scoping note setting out the proposed direction of the project. The white papers also establish an international Expert Panel to provide guidance and advice throughout the project research phase. Each white paper then conducts a Systematic Review of the evidence base to expose the full range of existing evidence, analysing this evidence to uncover pertinent data and emergent trends. White papers are then published as accessible, policy-facing reports that present the evidence and interpret findings for a non-expert audience.

This document presents issues of scope and structure for White Paper 4, which will investigate the evidence surrounding the use of gas in heavy goods vehicles and shipping. This will be examined in the context of both carbon and local air pollution abatement.

2. Background

Emissions in the transport sector, both Greenhouse Gases (GHGs) and air pollutants (including oxides of nitrogen (NO_x) oxides of sulphur (SO_x) and particulate matter (PM)), are an increasingly important issue in global energy systems. Progress on GHG emissions from transport has been relatively slow, with shipping GHG emissions particularly difficult and currently outside global climate agreements (Rehmatulla *et al.* 2017). In addition, local air pollutants arising from vehicles, such as nitrogen oxides, sulphur oxides and particulates, are a growing concern for human health (Kampa & Castanas 2008; EEA 2016). Natural gas has been suggested as an alternative transport fuel to help combat these emissions, particularly in shipping and goods transportation given the range requirements in these vehicle types (Fevre 2014; Kollamthodi *et al.* 2016). However, there is some disagreement as to the potential for natural gas to provide significant improvements over emissions emerging from the current transport system (Kollamthodi *et al.* 2016).

In road transport, diesel is the fuel most commonly used in heavy goods vehicles (HGVs) (IEA 2017). Successive development of emissions regulations in regions such as Europe and the United States, including the reduced sulphur content of diesel fuel, have progressively improved both GHG and air pollution emissions of new vehicles (Kollamthodi *et al.* 2016). This has reduced the margin between emissions of diesel and natural gas fired vehicles. In shipping a number of different fuels are used, representing oil fractions from diesel up to more viscous fuel oils (EIA 2015).

Regulations in different ports and enclosed water ways often require use of low sulphur fuel oils or diesel in order to reduce local air pollution impacts. There is some debate as to the impact on GHG emissions of moving to compressed natural gas or liquefied natural gas (Fevre 2014; Kollamthodi *et al.* 2016). However, there appears to be a more positive impact on local air pollution through a move to natural gas based fuels in shipping (Fevre 2014; Kollamthodi *et al.* 2016).

A key issue for natural gas use for both road transport and shipping emissions is that supply chain emissions of methane, and methane emissions from uncombusted methane in exhaust gasses (methane slip) can increase total GHG emissions significantly, given the high climate forcing characteristics of methane.

Understanding the extent of supply chain leakage and methane slip are key to understanding the value of a transition to natural gas fuels in road transport and shipping.

A further issues is to what extent decarbonised hydrogen may provide an alternative gas transport fuel that may compete with natural gas in some instances.

Outstanding questions include on what time scale this technology option might be widely available, what emissions are produced, both GHG and local air pollution, and how does this compare to natural gas?

White Paper 4 will begin by investigating the emissions arising in both HGVs and shipping, clearly describing the relevant aspects of both transport mode. The white paper will then present the available evidence on GHG emissions, and air pollution emissions for both HGVs and shipping. The importance of supply chain and methane slip emissions will then be explored. On the basis of the available evidence the report will conclude on the scope for natural gas to reduce both GHG and air pollution emissions from HGVs and shipping against current emissions levels. This will include the sensitivity of total emissions to supply chain and methane slip emissions, bounded by the best evidence around the range of these two variables.

An SGI White Paper in this area, including systematic review of the available evidence, has the potential to:

- clarify the extent to which the issues around natural gas in HGVs and shipping are adequately addressed in the existing evidence base;
- provide an assessment of the global potential for natural gas to reduce both GHG emissions and local air pollution from HGVs and shipping;
- provide a fair comparison of the range of existing evidence in a clear, transparent and rigorous review;
- identify the remaining research and data gaps; and
- provide clear concise evidence and analysis to policy makers.

3. Guiding question and scope

The guiding research question proposed for White Paper 4 is as follows:

What is the evidence that natural gas can play a role in reducing greenhouse gas emissions and local air pollution from heavy goods vehicles and shipping?

The potential scope of this question is broad and it is therefore necessary to define a confined scope within this question that allows for suitable analysis within the resource constraints of the project. A number of points designed to help inform project scope are presented below.

- The white paper will focus on the use of natural gas as a fuel in shipping and HGVs. These vehicles may be most suitable for gas energy vectors given the range/energy storage requirements and utilisation of these vehicles and the difficulties in supplying this utility through electricity. The extent to which this scope is justified will be presented in the early sections of the report.
- An examination of the evidence on alternative fuels in shipping and HGVs will also be undertaken. Such alternatives include incremental efficiency/emissions improvements of traditional liquid fuels, battery electric drivetrains, hydrogen fuel cell drive trains and the use of liquid and gaseous biofuels.
- The literature on the historical performance of the incumbent HGV and shipping options and fuels will be examined to provide a suitable baseline. This will provide appropriate context with which to examine the future alternatives.
- The key impacts to be considered will be based on GHG emissions, air pollutants (specifically NO_x, SO_x and PM) and economic cost.
- The human health benefits associated with reducing local air pollution from shipping and HGVs will be discussed but the impact of air pollution reduction on human health outcomes will not be quantified.
- The scope of the evaluation will include the full life cycle of the fuel, including upstream supply chains and end-use, allowing for drivetrain efficiencies.
- The geographical and policy context of studies examining gaseous fuels in shipping and HGVs will be examined. The appropriateness of gaseous transport fuels will likely vary with geographical context and efforts will be made to quantify this relationship.
- The report will primarily focus on the timeline to 2050.
- The final aspect of the report scope is to investigate the extent to which natural gas in shipping and HGVs can contribute to the GHG reductions needed to remain within 2 degree climate scenarios, and NO_x, SO_x and PM emissions. The proportion of emissions reduction to the overall emissions from the transport sector will be compared to provide some context with which to judge the potential for reducing HGV and Shipping emissions using natural gas.

4. Methodology

The SGI White Paper Series conducts Systematic Reviews of the existing evidence base, expert elicitation exercises to leverage existing tacit knowledge, aided by primary research to fill apparent research gaps. These techniques are the key features of the policy research approach known as Evidence –Based Policy and Practice (EBPP) (Sorrell 2007). This approach was originally developed in areas of public policy research including healthcare, education, social work and criminal justice (Sorrell 2007). It is informed by the approach adopted by the Cochrane Collaboration in the assessment of evidence in healthcare policy (King *et al.* 1994).

Systematic Reviews are designed to screen the literature in a systematic and transparent way to identify and critically analyse evidence relevant to answering a pre-determined question (Khan *et al.* 2003). The review process followed by the SGI is an adapted version of the process developed by the UKERC TPA (Gross *et al.* 2006), represented by the generalised procedure seen in Figure 1.

Figure 1: The methodological procedure followed by the SGI White Paper Series, including systematic review and expert elicitation.

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						
<ul style="list-style-type: none"> • Write a scoping note, outlining aims and search and review protocols 	<ul style="list-style-type: none"> • Appoint expert panel • Solicit expert panel comments on scoping note • Finalise aims and search and review protocols 	<ul style="list-style-type: none"> • Apply protocol to literature search • Detailed and transparent 'trawl' • Identify relevant sources 	<ul style="list-style-type: none"> • Apply protocol for evaluation and synthesis of literature 	<ul style="list-style-type: none"> • Write preliminary draft report 	<ul style="list-style-type: none"> • Solicit expert panel comments on draft report • Revise draft report 	<ul style="list-style-type: none"> • Design and format report • Publish and publicise report • Launch event
OUTPUT						
<ul style="list-style-type: none"> • Submit scoping note to expert panel 	<ul style="list-style-type: none"> • Expert panel review of scoping note 	<ul style="list-style-type: none"> • Literature database 		<ul style="list-style-type: none"> • Draft report 	<ul style="list-style-type: none"> • Expert panel review of report 	<ul style="list-style-type: none"> • Publish report

The White Paper will also establish an international Expert Panel to provide guidance and advice throughout the project research phase. These experts will be drawn from the academic, government, industry and third sectors to provide a range of perspectives from relevant stakeholder groups. Consulting key experts throughout the process will ensure that the White Paper delivers outputs that reflect the needs of

relevant stakeholders and adequately answers the research question (Higgins J. P. T. & Green 2011).

5. Identifying evidence

Evidence from both peer-reviewed and grey literature will be identified by entering Boolean combinations of pre-determined search terms (Table 1) in the following databases and websites:

- Peer reviewed academic journals
 - Science direct
 - Web of science
- Web search engines
 - Google scholar
 - World cat
- Technical reports and strategy papers from key stakeholders, including:
 - At the UK level: The Department of Business, Energy and Industrial Strategy (BEIS) The Department for Transport (DfT), the Committee on Climate Change (CCC), The Low Carbon Vehicles Partnership (LowCVP), Innovate UK, Transport for London (TfL), The Greater London Authority (GLA), the Energy Technologies Institute.
 - At the International level: The National Renewable Energy Laboratory, the Energy Information Administration, The European Commission, the Joint Research Centre, The International Energy Agency (IEA), the Intergovernmental Panel on Climate Change.
- Websites of relevant organisations, including, but not limited to:
 - Caterpillar
 - TOTE
 - General Dynamics NASSCO
 - IVECO
 - Rolls-Royce
 - DNV GL
 - IMO
 - OECD
 - IEA
 - MARAD (US Department of Transportation Maritime Administration)
 - EMSA (European Maritime Safety Agency)
 - IMO (International Maritime Organisation)

Table 1: List of search words used to filter the databases

Vehicle	Emissions	Regulations	Decarbonisation	Modelling	Geographical areas
Heavy Goods Vehicles	Emissions	International	Decarbonis*	Model*	US
HGV	NOx	Maritime	"Low carbon"	Scenarios	"United States"
Low carbon vehicle	SOx	Organisation	"Zero carbon"	Strategy	EU
LCV	Particulate*	IMO	"Energy transition"	Plan*	"European Union"
Zero Emissions Vehicle	PM*	EURO	Bridg*	Design	UK
ZEV	Greenhouse Gas*	ZEV	"Energy shift"	"Whole systems"	"United Kingdom"
Transport Methane	GHG	Policy Regulation		"system optimisation"	"The Netherlands"
Natural gas	Carbon Dioxide	Mandate		"Cost optimisation"	Japan
LNG	CO2	MARPOL		"integrated energy model"	Korea
CNG	Methane slip			"energy system model"	Germany
Hydrogen				MARKAL	
Battery electric				ESME	
Ship*				TIMES-UCL	
Vessel				UKTM-UCL	
Cargo ship				TIAM-UCL	
Bulk carrier				TIAM-	
Container ship				Grantham	
Tanker				RESOM	
				AUB	
				DynEMo	
				NHM	
				SERA	
				ReDS	
				PLEXOS	
				GREET	

Note: These terms and categories may be revised during the course of the project.

Search results will be screened for relevance, according to pre-determined inclusion criteria (Table 2). Results will be screened first on the basis of titles and abstracts, with subsequent judgements, if needed, made on the basis of content in the main article text. Members of the Expert Panel may also recommend evidence that has not been returned by the search strategy described above.

Table 2: Inclusion criteria governing the screening process

Inclusion criteria
<ul style="list-style-type: none"> • Studies that address some relevant aspect of the guiding research question • Studies undertaken by experts and/or representing the opinions of key stakeholders • Studies that are in English • Studies that can be found online

Note: Evidence discovered through expert elicitation may not be available online

The White Paper will identify and codify key information of each of the retained results, including, but not limited to:

- Geographical region
- Vehicle type/fuel type
- Emissions type/emissions rate
- Model(s) used
- Economics of options
- Regulatory context
- Timescale//time horizon

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