Questions & Answers:

Filming methane slip on board the MSC World Europa

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T&E embarked on the cruise ship *MSC World Europa* in June 2023 to film potential methane slip emanating from the ship's funnels. The details below answer some of the questions that have been raised following the publication by Bloomberg on July 31st, 2023, of the article "The invisible climate impact of a cruise ship" linked to this investigation.

What camera did you use to detect methane slip?

The infrared camera that T&E used for this investigation is the Teledyne FLIR GF320. This camera has a spectral filter that allows it to detect various hydrocarbons – including methane – which must have at least 2 degrees Celsius temperature difference between the emission plume and the background. Optical gas imaging cameras of this type are often used by the gas industry to locate potential gas leaks in their infrastructure.

Who did T&E work with to film those images and review their accuracy?

To ensure that the camera was detecting hydrocarbon slip and not water vapour, the camera was operated by a level 2 thermographer certified by the Infrared Training Center. The thermographer works for TP Europe, a Dutch company which works on a regular basis with the oil & gas, and petrochemical industries to detect emissions. T&E then asked for a optical gas imaging technical assessment based on the infrared camera images which was provided by a level III certified thermographer from TCHD Consulting, a U.S.-based company that provides thermal and environmental consulting services. This assessment is available here.

If the FLIR camera can detect various types of hydrocarbons, why would you assume that the slip "almost certainly" includes methane?

What the infrared camera shows is a mix of uncombusted/partly combusted hydrocarbon emissions. LNG used as a main fuel by the cruise ship is composed of 87.3-99.7% of methane depending on its geographical origins and the treatment process, and can include traces of

compounds such as ethane and propane. The combustion of LNG generates CO2 and water vapour, but because of incomplete combustion and ambient conditions which are inherent to the process, uncombusted methane (CH_4) emissions are released into the atmosphere.

Can the Teledyne FLIR camera quantify the amount of methane that escapes into the air?

No, though the Teledyne FLIR camera can detect hydrocarbon emission plumes, they cannot be quantified after combustion.

How could newly-built ships powered with LNG let methane slip in the air?

All ships that use an internal combustion engine with LNG let more or less methane escape into the air depending on the engine type. This includes the five Wartsila 4-stroke 14V46DF engines the *MSC World Europa i*s equipped with. The IMO estimates that this type of four-stroke, low pressure engine lets on average 3.5% of methane escape into the air. The European Union, on the other hand, estimates that this type of engine lets on average 3.1% methane escape. Several studies have measured CO2 and methane emissions on LNG-powered ships at sea. They estimate that the amount of methane that slips into the air varies between 2.2% to 8% with a significant variability linked to the load.[1]

How do you know the ship was powered with LNG and not MGO?

The company MSC Cruises announced via a press release that the vessel MSC World Europa would be using LNG as a marine fuel during the entire summer period and started bunkering LNG for the first time on April 15th, 2023, via the LNG bunkering ship *Gas Vitality.* To ascertain that information, T&E verified that the ship did bunker LNG to the cruise ship by following the vessels' trajectories and activities via Automatic Identification System (AIS) data. The AIS data showed that the cruise ship started bunkering LNG on April 22nd, 2022. In addition, the bunkering of LNG took place during the filming period. While the vessel used MGO as a pilot fuel, it relied on LNG for the majority of trajectories as it bunkers LNG every Saturday in the Port of Marseille.

What are the methane slip emission factors agreed at the IMO and EU levels?

[1] Balcombe, P., Heggo, D. A., & Harrison, M. (2022). Total Methane and CO2 Emissions from Liquefied Natural Gas Carrier Ships: The First Primary Measurements. Environmental science & technology, 56(13), 9632–9640. https://doi.org/10.1021/acs.est.2c01383 & Lehtoranta, K., Kuittinen, N., Vesala, H., & Koponen, P. (2023). Methane Emissions from a State-of-the-Art LNG-Powered Vessel. Atmosphere, 14(5), 825. https://doi.org/10.3390/atmos14050825

The emission value from the International Maritime Organisation and the European Union are available below.

Engine type	**Fuel**	**CH_4 slip (% of fuel) - EU emission value**[2]	**CH_4 slip (% of fuel) - IMO emission value**
Otto Cycle Dual Fuel Four-stroke Low Pressure	LNG	3.1%	3.5%
LBSI (Lean Burn Gas Engine)	LNG	2.6%[3]	2.6%
Otto Cycle Dual Fuel Two-stroke Low Pressure	LNG	1.7%	1.7%
LNG Diesel Dual Fuel Two-stroke High Pressure	LNG	0.20%	0.15%

To facilitate the understanding of the methane slip values from the IMO, these have been converted as a percentage of the fuel. The table below provides more details on the conversion method.

[2] The CH_4slip emission values are available under the Annex II - default emission factors from the EU regulation of the European Parliament and of the Council on the use of renewable and low-carbon fuels in maritime transport

[3] Figure extracted from the Fourth International Maritime Organisation Greenhouse Gas Study 2020.

Engine type	Fuel Type	CH_4 slip (g/kWh)[4]	Specific Fuel Consumption (LNG/kWh)[5]	Calculation method & Results
Otto Cycle Dual Fuel Four-stroke Low Pressure	LNG	5.5 gCH_4/kWh	156 gLNG/kWh	5.5 gCH_4/kWh / 156 gLNG/kWh = 0.035) CH_4 Slip = 3.5%
LBSI (Lean Burn Gas Engine)	LNG	4.1 gCH_4/kWh	156 gLNG/kWh	4.1 gCH_4/kWh / 156 gLNG/kWh = 0.026 CH_4 Slip = 2.6%
Otto Cycle Dual Fuel Two-stroke Low Pressure	LNG	2.5 gCH_4/kWh	148 gLNG/kWh	2.5 gCH_4/kWh / 148 gLNG/kWh = 0.017 CH_4 Slip = 1.7%
LNG Diesel Dual Fuel Two-stroke High Pressure	LNG	0.2 gCH_4/kWh	135 gLNG/kWh	0.2 gCH_4/kWh / 135 gLNG/kWh = 0.0015 CH_4 Slip = 0.15%

Further information

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[4] The CH_4slip values per engine type are available on "Table 6 – proposed CH_4 emissions factors for the Fourth IMO GHG Study" available on page 280 of the Fourth International Maritime Organisation Greenhouse Gas Study 2020.

[5] The specific fuel consumption is available under the "Table 19 - The SFCbase given in g/kWh for different engine and fuel types, and year of built" available on page 71 of the Fourth International Maritime Organisation Greenhouse Gas Study 2020.