Testimony of Robert W. Howarth, Ph.D.
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House of Oireachtas, Ireland
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My name is Robert Howarth. I am an Earth systems scientist with a Ph.D. awarded jointly by MIT and the Woods Hole Oceanographic Institution. I am the *David R. Atkinson Professor of Ecology & Environmental Biology* at Cornell University in Ithaca, NY, USA. I have been a tenured professor at Cornell since 1985, and I have conducted research and taught on climate change since 1980. My testimony is based on my best professional knowledge; it should not be construed as representing Cornell University.

I am an expert on the global methane cycle, on the role of methane as a driver of global climate change, and on methane emissions from the oil and gas industry. I am the lead author of the first ever peer-reviewed analysis of methane emissions from shale-gas development from high-volume hydraulic fracturing (Howarth et al., 2011, *Climatic Change Letters*, 106: 679) and have published ten additional papers on this topic in the past 8 years. My research on methane and shale gas is cited more in the peer-reviewed literature than that of any other scientist, with more than 2,700 citations. I have given hundreds of presentations on shale gas and climate change, including a briefing to senior staff in the Executive Office of the President in the White House.

Shale gas is a form of natural gas obtained from shale rock using high-volume hydraulic fracturing and high-precision directional drilling. These technologies have only been used by industry in the past 15 years, and virtually all shale gas ever produced has been produced in this century, largely in the last decade, and almost entirely in North America. Two thirds of the increase in production of natural gas over the past decade globally has been shale gas in the United States. Natural gas production in the United States is now dominated by shale gas, and if Ireland were to import LNG from the United States, it would largely be shale gas.

Methane is the major component of natural gas, including shale gas. Methane is an incredibly powerful greenhouse gas, more than 100 times more powerful than carbon dioxide compared gram to gram. Of the current global warming, methane contributes approximately 1 watt per square meter compared to 1.7 watts per square meter for carbon dioxide. The Earth's climate system responds more quickly to methane than to carbon dioxide, and reducing emissions of methane is critical to reaching the United Nations' COP21 target of keeping the planet well below 2^{o} compared to the pre-industrial baseline. If we do not reduce methane emissions, the Earth will shoot through the 2^{o} mark within the next 20 to 30 years, with devastating consequences.

Unfortunately, society has not so far acted to reduce methane emissions. Rather, methane in the atmosphere has been rising rapidly over the past decade. My latest research, published this summer by the European Geolosciences Union in the journal *Biogeosciences* (volume 16, pages 3033–3046), demonstrates that shale gas development in North America is the single largest driver of this increase in methane, accounting for one-third of the increase in global emissions from all sources.

Approximately 3.5% of the shale gas developed in the United States is emitted to the atmosphere as methane, due to both leaks and purposeful emissions at the well site, during processing and storage, and from transportation of the gas to consumers in pipelines. Because of these methane emissions, the use of shale gas in the United States has an even greater negative impact on the climate than does coal, when considered on the time scale of the next 2 decades.

LNG imported to Ireland from the United States would have an even greater greenhouse gas footprint. To liquefy and transport the gas requires a substantial amount of energy: to import one cubic meter of gas as LNG would require 1.2 cubic meters of gas to be produced, with 0.2 cubic meters consumed to produce and transport the LNG (Hardisty et al, 2012, *Energies*, 5: 872-897). I therefore estimate that the use of shale gas imported as LNG to Ireland would create greenhouse gas emissions of 156 g CO2-equivalents per MJ, or a foot-print 44% greater than that of coal (see Figure). This is a minimum estimate, since it does not include the additional methane emissions associated with storing and transporting the LNG: LNG is kept in liquid form by allowing some methane to "boil off," resulting in evaporative cooling. In a typical voyage, 2 to 6% of the LNG is lost as gaseous methane due to this boil off. Usually, the methane is used as fuel to help power the ship, but it seems highly likely that some is emitted to the atmosphere, although I am aware of no data on this emission.

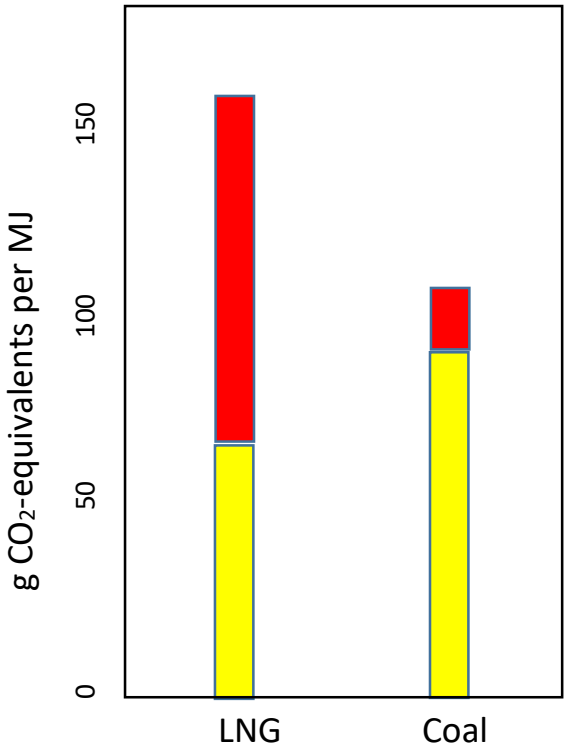

Figure 1. The greenhouse gas footprint of LNG imported to Ireland from the United States compared to coal. Emissions of carbon dioxide are shown in yellow. The red bars indicate methane emissions in units of carbon dioxide equivalents. See below for estimation details.

From the standpoint of climate change, LNG is a very poor fuel choice. I urge Ireland to prohibit the importation of fracked shale gas from the United States. Thank you for the opportunity to speak to you.

Estimation of greenhouse gas emissions: Emissions of carbon dioxide are as reported in my 2011 paper and are based on data from the US Department of Energy. Emissions of methane from coal are as reported in 1996 by the Intergovernmental Panel on Climate Change. Methane emissions for LNG are based on a 3.5% emission rate for shale gas in the United States, as determined in my 2019 *Biogeosciences* paper, and the estimate of Hardisty et al. (2012) on the amount of natural gas consumed in the process of producing and transporting LNG. Methane emissions are converted to carbon dioxide equivalents using the 20-year global warming potential of 86 reported by the Intergovernmental Panel on Climate Change in their 2013 synthesis report.