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Measurement, Reporting, and Verification of Methane Emissions from Natural Gas and LNG Trade:

creating transparent and credible frameworks

GAS

ENERGY TRANSITION

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Preface

This paper builds on a body of work that Jonathan Stern has been developing on the topic of gas in a decarbonising energy economy over the past five years. The theme of methane emissions, which is the topic of this paper, has become a critical one as it has been used as a stick with which to challenge the perceived environmental benefits of gas versus other hydrocarbons, especially coal. However, as Professor Stern has pointed out on a number of occasions, providing an answer to the question of whether methane emissions in the gas value chain are serious enough to undermine the potential role of gas in the energy transition, especially as a bridge fuel to back up renewables in power generation, relies on having accurate and credible data. As such, the measurement, reporting and verification of methane emissions using a transparent and globally accepted methodology has become a crucial issue, as highlighted by research from the IEA, the publication of an EU Methane Strategy and Regulation, and the announcement of the Global Methane Pledge at COP26. Given the level of public scrutiny and policy focus on this issue, it has become absolutely vital that the gas industry takes proactive steps to create and implement a global plan both to reduce, but first to accurately document, methane emissions, and in this paper Stern outlines the first steps being taken in this direction and assesses the progress to date. He focuses on the major gas exporters to Europe and carbon neutral LNG as examples of the challenges that are being faced, and examines the methodologies being developed by industry groups and companies as they seek to establish a template for future reporting. Most importantly, though, he underlines again the need for rapid action if the gas industry is to have a significant long-term future in a decarbonising world and lays out recommendations for future action. He also establishes a platform for future research by the Institute as part of its Energy Transition Research Initiative as we continue to monitor and analyse this important topic.

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Thanks to Catherine Gaunt for her stellar editing and Kate Teasdale who did everything else with her customary good humour and efficiency.

I am solely responsible for all and any errors and omissions which remain, and all opinions and interpretations.

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The Global Methane Pledge to reduce emissions by at least 30 per cent by 2030, signed by more than 100 countries at the COP26 Conference in November 2021, moved methane on to the global political agenda and gave it a much sharper public focus. Atmospheric concentrations of methane are rising much faster than those of carbon dioxide, and it is a much more powerful greenhouse gas.

Urgency

Urgency to reduce methane emissions from fossil fuels by at least 75 per cent by 2030 (relative to 2020) has been recognized and recommended by both UNEP's Climate and Clean Air Coalition and the International Energy Agency as an essential contribution towards achieving net zero global energy emissions by 2050, and as the fastest and lowest-cost means of reducing the rate of climate warming.

The EU Methane Strategy proposed the establishment of a methane intensity standard for domestically produced and imported fossil fuels, with an initial focus on emissions from natural gas and LNG imports. However, in the proposed EU Regulation, the intensity standard was replaced by an obligation on importers to provide information for the establishment of a methane transparency database. Not until the end of 2025 will the EU have gathered sufficient data on emissions to develop a methane standard which endangers the 2030 targets for reducing emissions; and dictates that methane emission frameworks need to be negotiated on a much shorter time scale.

Measurement Reporting and Verification (MRV) of data

MRV of emissions from imported gas and LNG are best divided into three supply chain segments:

- From production (upstream) to the border of the exporting country.
- From the border of the exporting country to the border of the importing country.
- Emissions from within the importing country.

It should be expected that emissions from each of these segments will change over time with changes in: the sources of production, supply routes (especially for LNG), and end-uses of gas in the energy balance of importing countries.

Three major requirements for creating credible MRV of emissions are:

- to move measurement and reporting of methane emissions from standard factors – either engineering-based or from US EPA data – to empirical (Tier 3) measurements, and to reconcile bottom-up (ground level) and top-down (satellite/aircraft/drone) observations.
- to ensure that data measurement and reporting has been verified and certified by accredited bodies.
- to require asset-level emissions data to be transparent and publicly available. Failure to do so on grounds of 'commercial confidentiality' risks being interpreted as evidence that the data is not credible.

The International Methane Emissions Observatory (IMEO), has been given the tasks of collecting, collating, and publishing data submitted by companies from both the EU transparency database and the Oil and Gas Methane Partnership Version 2.0 (OGMP2) framework, recognized by the EU as the 'gold standard' for MRV of methane emissions. The European Commission and the IMEO are proposing to develop and publish a Methane Supply Index from the data which is collected, but for this to allow meaningful comparisons all the major companies involved in exporting gas and LNG to Europe would need to report emissions on a similar basis to OGMP2 which currently has very few members outside Europe.

Data sources and export supply chains

The UNFCCC and the IEA are major sources of public domain data on methane emissions for the six most important exporters of pipeline gas and LNG to Europe. Submissions to the UNFCCC database are not compiled using common methodologies, and data for non-Annex 1 countries are not up to date. The IEA Methane Tracker has current data which is regularly updated using a consistent (but not entirely transparent) methodology. Data from the Tracker and from companies and governments show that Norway has very low emissions, Nigeria and Algeria have the highest emissions; with the US, Russia, and Qatar being somewhere in between. Detailed examination of individual natural gas and

LNG export supply chains for these six most important suppliers to Europe shows how Norway has progressed MRV and reduced emissions to a much greater extent than other exporters. Complexity of US LNG export supply chains contrasts with the relative simplicity of Qatari chains. For Russian exports, the focus is on Gazprom's long transmission pipelines, while Algerian and Nigerian companies are only just beginning to address these issues.

Emissions from specific pipeline gas and LNG supply chains

MRV agreements and emission values with each exporting company, based on the specific characteristics of its export supply chain, need to be established. There will need to be multiple values based on different LNG and pipeline export supply chains. Buyers will need to establish these values with exporting companies and, in the case of state-owned companies, possibly also with governments. In four out of the six major suppliers to Europe, co-mingling of gas before it reaches the border of the exporting country makes it impossible to trace exported molecules back to the point of production. Qatar and Russia are the only countries where this may be possible for at least some routes. For Norway, Algeria, Nigeria and the US, assumptions will need to be made on averages of emissions arriving at their borders prior to onward pipeline transportation or loading on to an LNG tanker. MRV of emissions from onward pipeline and LNG transportation will provide a total value for emissions at the border of the importing country. Emissions from within the importing country are best determined by gas and LNG buyers and their regulator(s).

Taxes, prices and the GWP coefficient

How these emission values are used to determine taxes and prices for imported gas and LNG will depend on greenhouse gas legislation and regulation in the importing country. Elements of the EU's proposed Carbon Border Adjustment Mechanism may provide a useful template. If methane charges are to be based on CO_2 prices the global warming potential (GWP) coefficient, for conversion of methane into CO_2 equivalent, will be a key consideration for governments with 2050 GHG reduction commitments. Shortening the time horizon for the GWP of methane from 100 to 20-30 years would result in a 2-3-fold increase in CO_2 equivalent.

Asia and imports of `carbon neutral' LNG

The urgency for buyers of natural gas and LNG to provide credible MRV of emissions from imports to Europe – the largest gas importing region with the most climate-sensitive policies - is likely to spread to other major gas and particularly Asian LNG importing countries as it becomes increasingly necessary for companies and governments to account precisely for their emissions. In this context, 'carbon-neutral' LNG cargos are a highly problematic construct, lacking in transparency and therefore in environmental credibility. The term `carbon neutral' needs to be replaced by `greenhouse gas verified' LNG. The SGE and GIIGNL methodologies, and the study of Cheniere's 2018 cargos combined with the company's commitment to provide individual cargo emission tags from 2022, are important milestones in the creation of frameworks for establishing global LNG supply chain emission values. Any claim to carbon or (more precisely) GHG neutrality requires transparent MRV of individual cargo emissions matched with an equally transparent and equivalent offset.

Relevance for the future of natural gas, LNG and all fossil fuel trade

Although this study has focused on natural gas and LNG, the same argument can be made for emissions from imported oil and coal, with methane emissions from oil imports as important as (and in many countries more important than) those from pipeline gas and LNG. With increasing international and civil society pressures on governments and companies to accelerate fossil fuel phase-out, transparent MRV of methane emissions has become a non-negotiable requirement for traded fossil fuels. A lack of this information undermines claims that natural gas and LNG can play a significant ongoing role in the low-carbon energy transition. There are significant obstacles to agreement of enforceable legal and regulatory MRV frameworks, even on a bilateral (let alone a global) basis. This paper has described the start of a journey to create credible and transparent documentation of methane emissions from natural gas trade, and emissions of all GHGs from LNG trade. But the longer that the international gas community takes to put transparent MRV frameworks in place, the greater the likelihood this will be construed as either reluctance or inability to reduce emissions, and that countries will adopt alternative energy options.

Recommendations

Methane emissions:

1. Standardized methodologies and procedures for empirical measurement, reporting, and verification (MRV) of methane emissions from internationally traded gas and LNG should be agreed as soon as possible, ideally by the end of 2022, between European buyers and their natural gas and LNG suppliers and endorsed by governments and the European Commission. Longer time scales will mean that the 2030 methane reduction targets cannot be achieved. Buyers of global LNG will need to adopt similar frameworks and time scales.

2. Negotiations on MRV of emissions between European buyers and governments, and their counterparts in exporting countries, should focus on persuasion combined with technical and financial assistance. Attempts to impose (what may be seen as) arbitrary standards are likely to result in prolonged international legal/regulatory disputes.

3. Corporate responsibilities for MRV of methane emissions should be established for three different segments of export supply chains: the wellhead to the border of the exporting country, the border of the exporting country to the border of the importing country, within the importing country.

4. Methane emissions values – in absolute terms and intensity per unit of supply – should be stated for the different segments and assets of export supply chains, setting out how these values were calculated. These values should be transparent and publicly available; disclosures of partial or generalized data on grounds of confidentiality risk being dismissed as 'greenwash'.

5. Importing governments need to take a position on the most appropriate time horizon, and hence global warming potential (GWP) coefficient, for conversion of methane into CO_2 equivalent, especially if charges for methane emissions are related to those of CO_2. The adoption of COP21 and net zero GHG reduction targets for 2050 calls into question the continued use of a GWP with a 100-year time horizon.

Emissions from LNG trade:

1. The term 'Carbon Neutral LNG' is a misnomer and should be replaced by: 'Greenhouse Gas Verified LNG Cargo' which should provide a transparent GHG content for the cargo (subject to approved MRV procedures) delivered to the regasification terminal of the importing country.

2. Any offset of emissions based on the GHG content of an individual cargo of LNG should be a separate and transparent transaction, verified by accredited bodies.

1. Introduction and rationale:

This paper is based on a proposition that companies selling any fossil fuel – either domestically or internationally – need to provide an accurate and verifiable estimate of the greenhouse gas (GHG) emissions footprint of the fuel. Governments and regulators, but also end-consumers, will increasingly demand transparent and credible estimates of GHG emissions of the fuels and energy from both domestic and imported sources. The lower the emissions of an energy source, the more desirable and valuable it will become in a decarbonizing world. This may be particularly relevant for internationally traded fossil fuels delivered to countries with stringent GHG reduction targets such as European Union (EU) member states. This paper focuses on a limited subset of these issues: the measurement and regulation of methane emissions from internationally traded gas with a dual focus on European imports and global LNG trade.[1]

In the early years of the energy transition, natural gas and LNG were hailed by some as a potential 'bridge fuel' which could play a substantial role due to lower combustion emissions relative to other fossil fuels and particularly coal. More recently, an increasing focus on methane emissions from gas and LNG has cast doubt on the advantages of gas as a transition fuel, both in general and in relation to other energy options, and has led to assertions that fossil natural gas must be phased out because it cannot decarbonize.[2] While a net zero world eventually requires the vast majority of unabated natural gas to be phased out, the speed of the phase-out could depend significantly on whether emission reductions can be accurately measured and credibly verified.

Credibility will require a detailed account of how emissions are measured (namely, which methodologies are used), how they are reported, and whether they have been verified by an independent accredited technical body or regulatory authority. This will require tracing the methane molecules from the point of sale to the point of production, including emissions from the three segments of the supply chain: from production (upstream) to the border of the exporting country; from the border of the exporting country to the border of the importing country; emissions from within the importing country after the pipeline gas or LNG has been delivered to the border.[3]

This study is a continuation of a previous paper published at the end of 2020.[4] Its purpose is to look at how measurement, reporting, and verification (MRV) of methane emissions frameworks need to evolve in relation to international gas and LNG trade. Transparency, and hence credibility, of these frameworks will be crucial to the future of international gas and LNG trade.

The paper is organized in six sections: this first outlines the extent, relevance, and urgency of the methane emissions problem. The second deals with emerging and proposed European Union regulatory frameworks. Sections 3 and 4 cover public domain data and assessments of emissions from the export supply chains of the six major suppliers of pipeline gas and LNG to Europe. The following section widens the discussion beyond Europe and beyond methane, to look at the development of carbon-neutral LNG cargos, and an overview of frameworks for MRV of greenhouse gas emissions from global LNG supply chains. Section 6 reverts to the focus on methane, describing the functions of the International Methane Emissions Observatory (IMEO), the Oil and Gas Methane Partnership's Version 2.0 framework and issues of confidentiality, certification and assurance.

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[1] This is not to suggest that carbon dioxide emissions from natural gas and LNG trade are unimportant; nitrous oxide is also an important greenhouse gas but is a relatively small contributor to emissions from natural gas export supply chains. For some countries, methane emissions from oil and coal trade could be as, or more, important than those from natural gas trade.

[2] For an academic exposition of this view see Von Hirschausen et al. (2021).

[3] This paper refers to 'segments' (rather than stages, boundaries, or scopes) of the export supply (not value) chain. This is to clarify the location of the physical assets from which MRV of emissions needs to be carried out, and therefore the corporate bodies and regulatory authorities which have responsibilities for those functions.

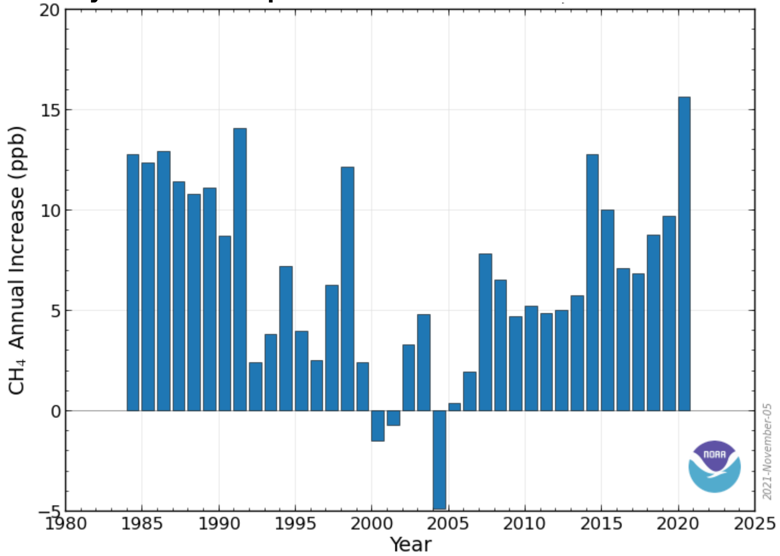
[4] Stern (2020).

Methane emissions – relevance and urgency

Greater attention is being paid to methane (CH4) emissions from all sources (natural and anthropogenic) because over the past decade atmospheric concentrations have been increasing much faster than previously, and in 2020 at the fastest rate since records began in the 1980s (Figures 1 and 2). The IPCC's 6th Assessment Report, published in 2021, stated that:[5]

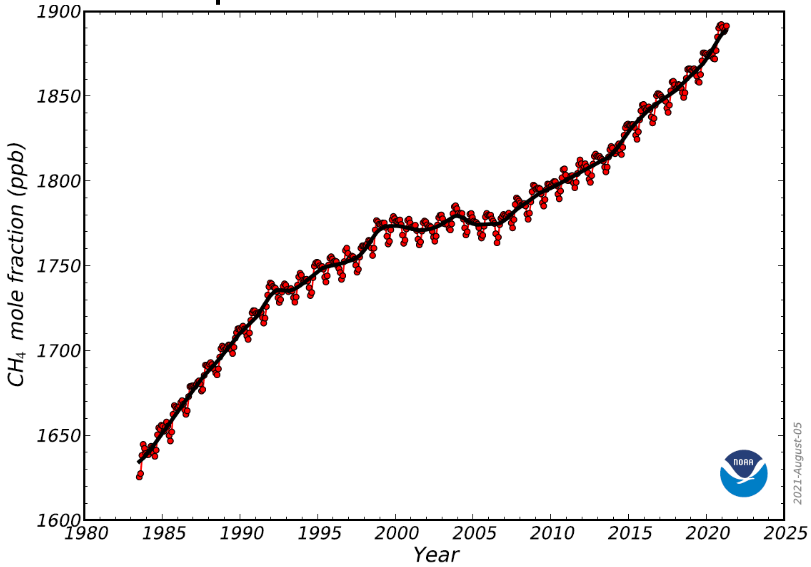
> 'From a physical science perspective, limiting human-induced global warming to a specific level requires limiting cumulative COP2 emissions, reaching at least net zero CO_2 emissions, along with strong reductions in other greenhouse gas emissions. Strong, rapid and sustained CH4 reductions would also limit the warming effect resulting from declining aerosol pollution and would improve air quality.'

Figure 1: Global monthly mean atmospheric methane levels 1980–2021



Source: NOAA (2021).

Figure 2: Annual trend in atmospheric methane concentrations 1980–2020



Source: NOAA (2021).

[5] IPCC (2021): *Summary for Policy Makers*, p. SPM-36.

Attention has become focused on methane because of the urgency to implement measures by 2030 which could reduce the warming impact of GHG over the next several decades. Methane is the second-largest contributor to warming after carbon dioxide and by far the biggest contributor of the non-CO_2 gases.[6] Recent research has concluded that:

> ' … while the potential to reduce methane emissions with existing mitigation methods varies considerably by sector, if deployed in parallel can cut expected 2030 methane emissions in half, with a quarter at no net cost. We find that full deployment of these available mitigation measures by 2030 can slow the global-mean warming over the next few decades by more than 25 per cent, while preventing around a quarter of a degree (centigrade) of additional global-mean warming in 2050 and half a degree (centigrade) in 2100. On the other hand, slow or delayed methane action leads to a 5 per cent or nearly 20 per cent increase in global-mean rate from 2030 to 2050 relative to fast action, respectively.'[7]

The Global Methane Pledge

The relevance and urgency of methane action is reflected in growing attention from governments. In September 2021, the US, EU, and seven additional countries committed to a Global Methane Pledge.[8] Two months later at COP26, the Pledge was launched announcing:[9]

> '… a collective effort to reduce global methane emissions by at least 30 percent from 2020 levels by 2030 which could eliminate over 0.2 degrees C warming by 2050. Participants also commit to moving towards using the highest tier IPCC good practice inventory methodologies, as well as working to continuously improve the accuracy, transparency, consistency, comparability, and completeness of national greenhouse gas inventory reporting … and to provide greater transparency in key sectors.'

By the end of 2021 the Pledge had 111 country signatories.[10] Also at COP26 the US and China signed a Declaration on Enhancing Climate Action with specific emphasis on cooperating:

> ' … to develop additional measures to enhance methane emission control, at both the national and sub-national levels. In addition to its recently communicated NDC, China intends to develop a comprehensive and ambitious National Action Plan on methane, aiming to achieve a significant effect on methane emissions control and reductions in the 2020s.'[11]

Despite this Declaration, China did not sign the Global Pledge, possibly due to the high methane emissions from its coal sector which could be a focus of future US–China cooperation.[12] Nevertheless the IEA considers China a 'committed country' with respect to methane reduction, due to the Chinese Oil and Gas Methane Alliance.[13]

Global warming potential (GWP) of methane relative to CO_2

A major analytical and policy issue impacting how methane emissions are reported concerns how to translate methane emissions into carbon dioxide equivalent. Methane is a much more potent greenhouse gas than carbon dioxide, although it has a much shorter atmospheric life. Emissions are very often reported in terms of carbon dioxide equivalent (CO_2e), which requires an assessment of the global warming potential (GWP) of methane. The most usual metrics are that the radiative forcing

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[6] Ibid, Figure SPM.2, p.SPM-8.
[7] Ocko et al. (2021).
[8] White House (2021).
[9] Full details of the Pledge can be found at https://www.globalmethanepledge.org/.
[10] Including the EU and the Federated States of Micronesia. Notable important gas importing and exporting countries absent from the list of signatories were: China, India, Russia, Qatar, Australia, Algeria, Egypt, Azerbaijan, and Turkmenistan. The Pledge also has 24 Supporters including: CCAC, EBRD, GMI, IEA, UNEP and 19 Foundations and Philanthropies.
[11] US State Department (2021).
[12] China is by far the largest global emitter of coal mine methane. IEA (2021), Figure 4.1, p.48.
[13] Ibid, p.22 and 40.

impact of methane is 28–36 times that of CO_2 measured over a 100–year time horizon, and 84–87 times over a 20-year horizon.[14]

IPCC Assessment Reports progressively raised the GWP for methane to 28 over a 100-year, and 84 over a 20-year, horizon in Assessment Report (AR) 5 published in 2014; but adding climate feedback mechanisms and oxidation, these figures increase to 36 and 87.[15] AR6, published in 2021, raised the GWP of methane to 29.8 over a 100-year horizon but seems to have reduced the 20-year horizon factor to 82.5.[16] With the adoption of COP 21 (Paris), and particularly of net zero, targets for 2050 there is a convincing case for taking a 20–30-year, rather than a 100-year horizon. The original agreement by the Conference of Parties (COP) did not rule out the use of shorter horizons, but 100 years is the standard which is near-universally used by governments and companies, many of which are also still using a GWP of 25 from AR4.[17] More details on GWP metrics can be found in Appendix 1.

As targets for GHG emission reductions and carbon budgets become increasingly stringent for governments and companies, the selection of the GWP time horizon becomes more crucial.[18] Using a time horizon of 2050 would produce a 2 to 3-fold increase in CO_2 equivalent emissions for methane compared with a 100-year horizon, and would substantially impact emission calculations and therefore the achievement of targets. GWP is the tip of a very large 'data iceberg' of methane analysis, the next layer of which is the different methods of measurement.

Bottom-up and top-down measurements

Appendix 2 shows estimates of global natural and anthropogenic emissions. These are measured by two methods – bottom-up (ground-level) and top-down (aerial), each of which has its own drawbacks and limitations, and neither of which can be regarded as 'correct'.[19] However, if they are reconciled for location and time using facility-specific operational data, the ultimate result will be as accurate as possible with current technology. Differences between bottom-up and top-down estimates and the ranges of uncertainty for both, shown in Appendix 2, give an indication of the difficulty of representing data as 'accurate'.

Top-down observations have been revolutionized over the past several years with satellite technology, particularly in relation to identifying super-emitters.[20] However, it is important to understand that satellites are currently unable to identify methane emissions from sites which are offshore, snow-covered, in marshy terrain, or tropical conditions. In relation to suppliers of natural gas to Europe this means that satellites cannot view any emissions from Norway (where all oil and gas production is offshore), Qatar (offshore), Nigeria (tropical), or the majority of Russian oil and gas production (snow-covered).[21] New satellites are being launched over the next few years with greater granularity of both

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[14] Balcombe et al. (2018), Table 3. provides 15 different climate metrics related to global methane impacts and their different values over three different time frames including: global temperature potential (used by a number of different sources), sea level rise potential, precipitation change potential, cost potential, and damage potential.

[15] Ibid, Table 2 which shows how the figures have increased over the different IPCC ARs. However, the AR5 recommendation has not formally been adopted, and in 2021 many governments and companies were still using a GWP of 25 (agreed at AR4) to report their emissions. Others are using different metrics, for example the IEA Methane Tracker (2021) uses figures of 85 over 20 years and 30 over 100 years.

[16] IPCC (2021), Chapter 7, Table 7.15, p.7–125. GWP-20 has a confidence factor of +/–11, the GWP-100 confidence factor is +/–25.8.

[17] As noted above, although AR5 established a GWP of 28 (further increased to 29.8 in AR6), this has not been formally agreed by governments.

[18] The CCAC cites a GWP impact of 84 over a 20-year period with no longer time horizon provided. https://www.ccacoalition.org/en/slcps/methane.

[19] Stern (2020), pp.5–6 has more detail on the pros and cons of bottom-up and top-down methods.

[20] In most countries, a relatively small number of sources account for a disproportionate share – usually 60–70% – of total methane emissions. These 'super-emitters' (usually classed as more than 0.5 tonnes/hour) are most easily identified by satellites. Kayrros – a company which produces satellite observations and data used by both the EU and the IEA – suggests that methane emissions from super-emitters equivalent to one gigatonne of CO_2 can be eliminated within two to three years. For more information on super emitters see Kayrros (2020) and Stern (2020), pp. 13–15.

[21] Ibid, pp.13–15 has more detail on satellite observations.

location and volume of emissions, which will help to standardize observations and assist in identifying and quantifying relatively small emission sources.

Importance of the fossil fuel sector

Although the Global Methane Pledge applies to reduction in all sources of methane, the emphasis of immediate action and the reference to 'high emission sources' has concentrated attention on the fossil fuel sector.

The UN Climate and Clean Air Coalition judged that:

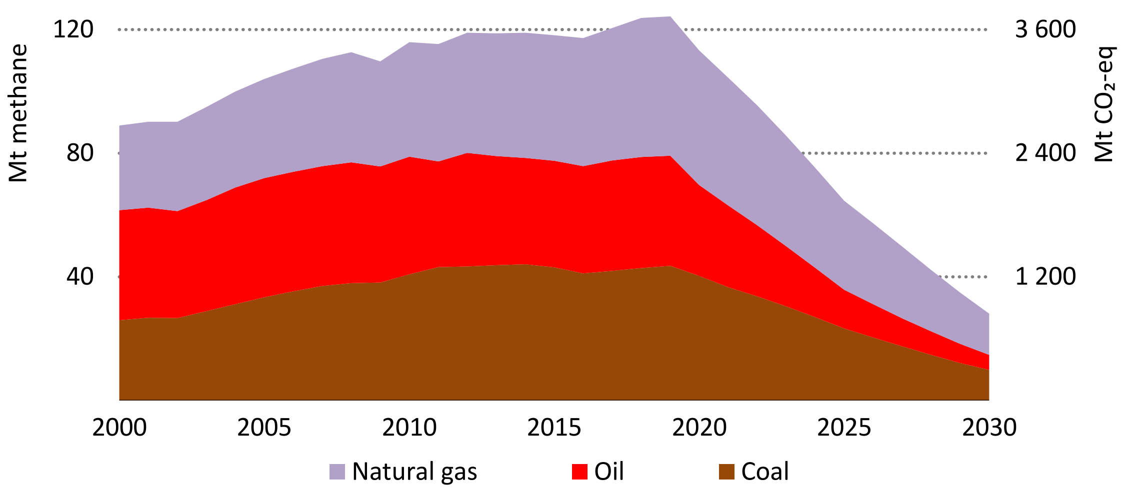
> ' … the fossil fuel sector has the greatest potential for targeted mitigation by 2030. Readily available targeted measures could reduce emissions from the oil and gas sector by 29–57 mt/yr and from the coal sector by 12–25 mt/year. Up to 90 per cent of the oil and gas measures and up to 98 per cent of the coal measures can be implemented at negative or low cost.'[22]

In the fossil fuel sector, there are three main sources of emissions: venting and flaring which are deliberate acts, and fugitive emissions which are not deliberate and are often referred to as 'leakage'. The oil and gas sector accounts for 29–56 per cent of the 101 mt of methane emissions which the CCAC estimates could have

> 'enormous societal benefits [including] climate related benefits of reducing warming by ~0.15 °C by 2040 with a value of 0.2 °C over the longer term (~2017–2100)'.[23]

Emissions of methane from oil and gas production, processing, transmission, and storage operations have been identified as a large source of anthropogenic GHG emissions, elimination of which can be achieved most easily, quickly, and least expensively. The International Energy Agency (IEA) has asserted that eliminating 'all technically avoidable methane emissions' from fossil fuel sectors – or by around 75 per cent between 2020 and 2030 – is a key building block in achieving net zero emissions by 2050 (Figure 3).[24] This includes significant reduction of unburnt methane from incomplete flaring from (mostly) oil production, as well as emissions from abandoned oil and gas wells and coal mines.

Figure 3: Methane emissions from coal, oil, and natural gas in the IEA Net Zero Scenario



Source: IEA Net Zero (2021), Figure 3.5, p. 104.

[22] UN/CCAC (2021), p.13.

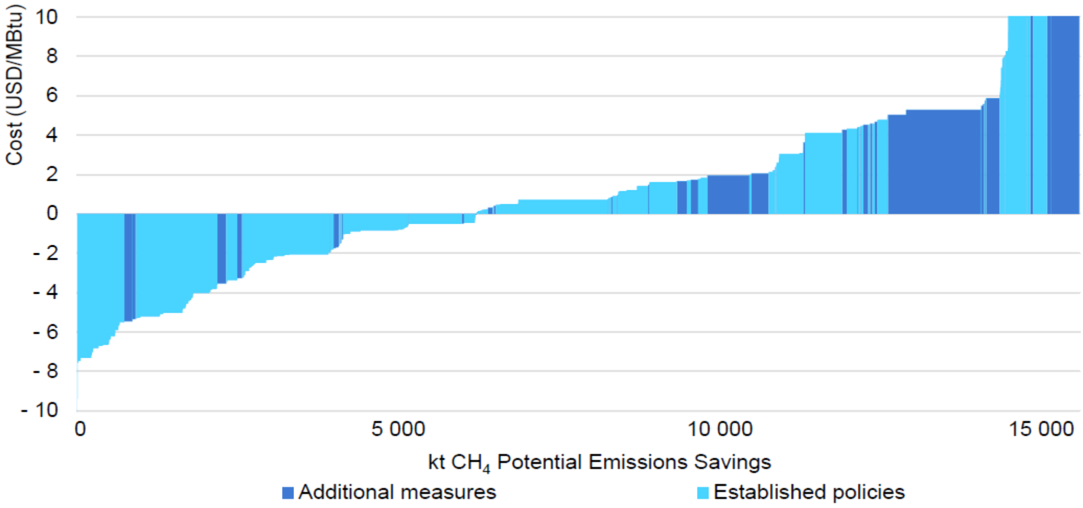
[23] Ibid, p.121, not including the benefits of reduced heat exposure, air pollution, premature deaths, hospital admissions, and crop losses. This is a significantly wider range, resulting in lower values, than the IEA proposal in Figure 3 to abate 75% of 120 mt. The very wide range is explained by the ranges in the global data (see Appendix 2) and emphasizes the general measurement uncertainties.

[24] IEA Net Zero (2021), p.104. One third of which is due to reduced fossil fuel consumption, but the majority is due to concerted efforts to deploy all available reduction methods and technologies.

The urgency is therefore that, within eight years, it is both possible and necessary to reduce methane emissions from fossil fuels by the very substantial amount which will be necessary for achieving overall GHG reductions, to be on track in 2030 towards meeting 2050 net zero targets.

IEA analysis concludes that it is possible to avoid more than 70 per cent of emissions with existing technology and 45 per cent at no net cost.[25] Figure 4 suggests that all of the measures would be cost-efficient if the resulting savings were exported at the international gas prices of 2021, but at 2020 price levels measures costing in excess of $3.50/mmbtu would probably not have been economic because (allowing for the costs of transportation) only in Asian and Asia Pacific importing countries did wholesale gas prices in that year exceed $4/mmbtu.[26] Moreover, if the saved gas had not been exported, then domestic gas prices in some countries would not have been sufficient for measures to be cost-effective. In both Algeria and Qatar, domestic wholesale gas prices in 2020 were significantly below $0.5/mmbtu and have not increased since. In Nigeria, wholesale prices were just below $4/mmbtu, but in Russia they were significantly below $2/mmbtu and in neither country are those levels likely to have increased significantly in 2021.[27] Average US prices of around $2.50/mmbtu in 2020 doubled to $5/mmbtu over the first nine months of 2021.[28]

Figure 4: Methane abatement cost curve for policies in committed* countries 2020



*countries which have made policy commitments and actions on methane emissions: Argentina, Canada, China, Cote D'Ivoire, European Union, Korea, Japan, Mexico, Norway, Nigeria, United Kingdom, and United States.
Source: IEA (2021). Figure 2.2, p.28.

2. EU legal/regulatory frameworks – the start of a (long) journey

The major focus of this study is methane emissions from pipeline and liquefied natural gas (LNG) trade, rather than emissions from domestic production. Increasing dependence on pipeline gas and LNG imports means that methane emissions embodied in those imports are several times those from declining European domestic production.[29] The reason is that, while greenhouse gas emissions are not

[25] IEA (2021), p.7.
[26] IGU (2021), Figure 28, p.35.
[27] Ibid, Figure 29, p.36.
[28] US Information Administration (2021), p.7.
[29] For different ways of calculating the ratio of domestic to imported emissions see Stern (2020), pp.19-21. The EU Regulation states that: `The Union is dependent on imports for 70% of its hard coal consumption, 97% of its oil consumption and 90% of its fossil gas consumption. There is no precise knowledge on the magnitude, origin or nature of methane emissions linked to fossil energy consumed in the Union but occurring in third countries'. European Commission (2021a), Recital 51, p.21.

high on the agenda of some exporting governments[30] and their companies, any emission standards imposed by importing country governments – particularly those in Europe – may increase the cost of access to EU (but also potentially global LNG) markets. This specific pipeline gas and LNG focus needs to be distinguished from methane emissions from exports of oil and coal. Where gas is co-produced with oil (associated gas), it is often impossible to decide how emissions should be allocated between gas and oil production.

Traded natural gas emissions also need to be distinguished from national emissions because the configuration of export supply chains in some (particularly large) countries is different to, and can be distinguished from, the rest of the (oil and) gas sector (see Section 4). There is a case for believing that a focus on MRV from exported supplies would create a positive feedback loop for addressing what may be a much larger volume of methane emissions from domestic gas (and oil) supply chains.

The EU Methane Strategy and Proposed Regulation

The EU Methane Strategy[31] published in October 2020 contained two major policy initiatives:[32]

- A global initiative to create an International Methane Emissions Observatory (IMEO), as a collaboration between the United Nations Environmental Programme (UNEP) and the European Commission[33] which would develop a Methane Supply Index (MSI) against which emissions from individual companies would be judged.
- Concentration on MRV of methane emissions from imported fossil fuel (gas, oil, and coal) supply chains but focusing initially on pipeline gas and LNG imports. This initiative proposed a diplomatic outreach campaign to persuade exporting countries to improve their MRV systems, the imposition of a default value for emissions should exporters fail to respond, and that:

> 'In the absence of significant commitments from international partners, the Commission will consider proposing legislation on targets, standards or other incentives for fossil energy consumed and imported in the EU.'[34]

The Strategy was transposed into a proposed Regulation on Methane Emissions Reduction in the Energy Sector, published in December 2021, with specific objectives: improving the accuracy of measuring emissions associated with energy produced and consumed within the EU, further effective reduction of methane emissions across the EU supply chain, and improving the availability of information to provide incentives for the reduction of emissions related to fossil energy imports.[35] For the oil and gas sectors, companies will have obligations in relation to monitoring and reporting, submitting leak detection and repair (LDAR) programmes, limiting (and to the maximum extent eliminating) routine venting and flaring of gas, and setting up an inventory of abandoned assets (namely oil and gas wells and coal mines that may still be leaking methane).[36]

Chapter 5 of the Regulation deals with emissions from outside the EU and includes only three Articles (27-29) on: importer requirements, a methane transparency database, and a methane emitters global monitoring tool.[37] Absent from the Regulation is the proposal from the Strategy on legislation for a methane standard or target.[38] This could be considered a disappointing outcome which will resonate in other regions where natural gas importers were expecting the EU to include stronger measures envisaged in the Strategy.

[30] As noted above, three important suppliers of gas to Europe – Russia, Qatar, and Algeria – were not among the first 111 signatories of the Global Pledge.
[31] European Commission (2020).
[32] The Strategy dealt with agriculture and waste as well as energy, but we focus here on the international fossil fuel proposals. More details of these proposals can be found in Stern (2020), pp.25–29.
[33] See Section 6 for more discussion of IMEO.
[34] European Commission (2020), p.17.
[35] European Commission (2021a), p.2.
[36] These are contained in Chapter 3 (Articles 12-18) of the Regulation, Chapter 4 is devoted to emissions from the coal sector.
[37] The latter is thought to refer to identification of super-emitters (see note 20).
[38] Mohlin et al. (2021) suggested how such a standard could be devised.

However, the Regulation gives notice that:

> `By 31 December 2025, or earlier if the Commission considered that sufficient evidence is available, the Commission shall examine the application of this Article (27), considering in particular..(d) security of supply and level playing field implications in case of possible additional obligations, including mandatory measures such as methane emission standards or targets...Where appropriate and based on the necessary evidence to secure full compliance with the international obligations of the Union, the Commission shall propose amendments to this Regulation to strengthen the requirements applicable to importers with the view to ensure a comparable level of effectiveness with respect to measurement, reporting, and verification and mitigation of energy sector methane emissions."[39]

This makes clear that the EU has not given up on the aspiration from the Strategy to create a methane standard or target for imported (fossil fuels including) natural gas and LNG, but will need time to gather information.[40] Without such information, attempts to introduce standards or targets may result in litigation due to the need to differentiate between different sources (and routes) of imported supply, (discussed below and in Section 4).

The Regulation therefore creates a two-step process the first step being a requirement for (domestic producers and) importers to provide information on:[41]

- the route followed by the energy to reach the EU;
- details of the measurement and reporting of emissions by the exporter in relation to UNFCCC reporting and OGMP2 standards (see Section 6);
- detail of regulation or voluntary measures to control emissions including LDAR, venting and flaring.

The second step would then be to pass the data collected by the importers to the new transparency database (and presumably also the IMEO) to create a Methane Supply Index (MSI). The Regulation makes a commitment to work with the IMEO to:

> `…set up a Methane Supply Index [to] provide methane emission data from different sources of fossil energy around the globe…thereby empowering buyers of fossil energy to make informed purchasing decisions on the basis of methane emissions of fossil energy sources'.[42]

The Regulation details the penalties for infringements which mostly apply to companies producing fossil fuels within the EU. Article 30{3(l)} includes penalties for `failure of importers to provide the information required in accordance with Article 27 and Annex VIII' (see Appendix 3). But it is not clear how importers are intended to obtain the information unless exporters are willing to cooperate, and what happens if importers are either unable (because they do not have the required systems in place) or unwilling to do so. Since it will be importers which will be paying charges for emissions associated with imports, when these are established, and will be liable for penalties for infringements, it will be important to establish procedures in the event of non-compliance by exporters.

Inability to provide the data can probably be remedied through technical and financial assistance from (a combination of) the EU, the importers themselves and their governments. Unwillingness to provide information, or disputes over the technical detail of MRV and the authority of the EU to impose such requirements on non-EU countries, may take longer to resolve.[43] It is not also clear to this author whether the information requirements (in Annex 8 (ii) and (iii) see Appendix 3) cover the entire import

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[39] Ibid, Article 27(3). Sub-paragraphs (a) through (c) refer to data collected by the monitoring tool, analysis by the IMEO and information on MRV measures of operators outside the Union from whom energy is imported.

[40] The Regulation (p.8) notes that in the consultations, `Stakeholders expressed widespread support for developing a robust MRV standard for methane emissions in the energy sector'.

[41] The information requirements are set out in Annex VIII of the Regulation which is reproduced at Appendix 3.

[42] European Commission (2021a), Recital 56, p.22. The IMEO commitment to setting up an index (see Section 6) is slightly less definite.

[43] For details of the verification requirements of the Regulation see Section 6.

supply chain or only emissions within the exporting country.[44] As the proposition which introduces this paper sets out, buyers of fossil energy can only (in the words of the Regulation) `make informed purchasing decisions' on the basis of MRV of emissions from full import supply chains.

Member state negotiations on the final form of the Regulation will probably require at least a year, until they are transposed into member state regulation. In addition, the MRV obligations will be phased in over a 1-4 year period after the Regulation enters into force, so it could be up to five years until they are all in place which may account for the end-2025 date before the Commission can consider introducing a methane standard or target.[45] Given the urgency to achieve reductions by 2030 (see Section 1) it will therefore be necessary for national governments, both in respect of their national and imported emissions, to introduce these obligations ahead of the EU Regulation coming into force.

The carbon border adjustment mechanism (CBAM)

Despite the omission of a methane standard in the proposed Regulation, the importer information requirements in Article 27 may anticipate the eventual introduction of such a measure. The carbon border adjustment mechanism (CBAM) is an instrument which forms part of the EU 'Fit for 55' package published in mid-2020.[46] CBAM is a mechanism which is designed to

> 'reduce the risk of carbon leakage … to ensure that the price of imports more accurately reflect their carbon content'.[47]

Because CBAM is a completely different mechanism. targeted at ensuring GHG parity between imported products and those produced within the EU and related only to CO_2 and not including fossil fuels, its relevance to any future methane standard may not seem obvious. However, many of the instruments and processes (considered and) proposed for CBAM provide a potential template for a methane standard.

From the CBAM options considered by the EU, a mechanism based on selected imported products in the form of certificates based on actual emissions was chosen.[48] Other elements of the CBAM Regulation relevant to any potential methane standard are:

- The declaration of emissions shall contain the total embedded emissions expressed per tonne of CO_2e emissions.[49]
- Embedded emissions in goods other than electricity shall be determined based on the actual emissions..When actual emissions cannot be adequately determined, the embedded emissions shall be determined by reference to default values..[50]
- The authorized declarant shall ensure that the total embedded emissions..are verified by a [accredited] verifier...[51]
- An authorized declarant may claim … a reduction in CBAM certificates ... in order for the carbon prices paid in the country of origin for the declared embedded emissions to be taken into account.[52]

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[44] The introduction to the Regulation (p.9) refers to, `..mitigating methane emissions linked to EU fossil fuel consumption but occurring outside the EU...applying to all methane emissions consumed in the EU covering the value chain..' This would suggest that the entire supply chain from production to the border of the importing country is included.
[45] Ibid, Articles 12-18.
[46] European Commission (2021b).
[47] Ibid, p.1. CBAM only relates to carbon dioxide and does not include methane. The sectors to which it will apply are: iron and steel, refineries, cement, basic organic chemicals, fertilizers, and electricity although the number of sectors may be expanded in future.
[48] Ibid, pp.7–8. Another option was an import tax paid by the importer when products enter the EU. The tax would reflect the price of carbon in the Union combined with a default carbon intensity of the products.
[49] Ibid, Article 6(2b).
[50] Ibid, Article 7(2) which refers to imported goods other than electricity. Article 7(3) deals with imported electricity
[51] Ibid, Article 8.
[52] Ibid, Article 9. But MRV for a methane standard could alternatively be based on the framework established for CO_2 emissions under its Emission Trading Scheme. This includes monitoring plans and reports from operators which are required to be

Compatibility with international trade law

The EU CBAM proposal document states that all the options considered

> 'were designed to take account of WTO requirements and of the EU's international commitments such as free trade agreements concluded by the EU or the Energy Community Treaty'.[53]

Detailed analysis of potential conflicts between a CBAM – and any future methane standard – and international trade law and WTO rules are beyond the scope of this study (and the competence of its author), but challenges to CBAM under WTO rules can be anticipated on grounds of protectionism and use by the EU of CBAM as an additional source of revenue.[54] A comprehensive study of border carbon adjustment (BCA) mechanisms warns that 'direct emissions measurement is not always practicable and may face legal challenges', and also that WTO and GATT rules may need to be amended, or require temporary waivers.[55]

Given these uncertainties, it is possible that no methane standard was included in the Regulation due to the risk of international litigation with major gas (and also potentially oil) suppliers which could take years to resolve. Given this possibility, and the need for urgent action, market leverage and financial inducements seem likely to be a better strategy than compulsion and confrontation, but it remains to be seen whether the import information requirements and the transparency database set out in the proposed Regulation will be sufficient to create the required momentum on emission reductions.

3. Public domain methane data for the six major external suppliers of gas to Europe

Achieving a comprehensive estimate of emissions from the export supply chains of all countries which export gas and LNG to the EU is a significant task, potentially threatening the urgency criterion identified above.

Table 1 shows that in 2020 six countries provided more than 90 per cent of European imports of pipeline gas and LNG. Moreover, more than half of the remaining 7–8 per cent of imports (from Azerbaijan and Iran) were delivered to Turkey, which is not an EU member state, and will therefore be less relevant in relation to emission standards.[56]

Table 2 shows the exporting companies associated with the countries in Table 1. In many cases exports are the responsibility of a single government-owned or controlled company, although very often in joint ventures with international oil and gas companies. In the case of the US, there are significant numbers of private companies involved in LNG exports from the different terminals listed in the table.

With the exception of the US, there are relatively limited numbers of companies which would need to be involved in a negotiation with the European Union in relation to any agreement on methane emissions from natural gas imports. While such negotiations will be complex, they may be possible to achieve on a timescale which reflects the urgency of the problem.

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verified by reports from 'accredited verifiers' and reviewed by 'independent assessors', for details see European Commission Implementing Regulation (2018a) and (2018b).

[53] European Commission (2021a), p.7.

[54] Barnes (2021) notes this has already been discussed in a meeting of the WTO Market Access Committee.

[55] Mehling et al. (2019).

[56] Turkey declined to be included as either an Annex 1 or Annex 2 country under the Kyoto Protocol and is the only G20 country which has not ratified the Paris Agreement and its national plans do not include ambitious GHG reduction targets. Climate Action Tracker (2020).

Table 1: European pipeline gas and LNG imports (2020) bcm

COUNTRY	IMPORT		TOTAL IMPORT	% TOTAL IMPORT		
	Pipeline	LNG		Pipeline	LNG	TOTAL
Russian Federation	167.7	17.2	184.9	52.3	15.0	42.5
Norway	108.9	4.1	113.0	34.0	3.6	26.0
Qatar	0	30.2	30.2	0	26.4	6.9
Algeria	21.0	13.9	34.9	6.6	12.1	8.0
Nigeria	0	14.6	14.6	0	12.8	3.4
United States	0	25.6	25.6	0	22.4	5.9
Other	*22.7	**8.9	31.6	7.1	7.8	7.3
TOTAL EUROPE	320.3	114.5	434.8	100	100	100

*Azerbaijan 13.4, Iran 5.1 and Libya 4.2. **Peru 0.4, Trinidad 5.2, other Americas 0.2, Angola 1.1, Egypt 0.4, other Africa 1.6.

Notes: table includes all European countries including Turkey and Ukraine (not including Belarus). Source includes a significant volume of gas (100.7 bcm by pipeline and 0.3 bcm of LNG) from 'other Europe', which is gas retraded within Europe but originally imported from countries in the table and therefore not included. Netherlands, an EU Member State (which exported 28.1 bcm to other EU countries in 2020), is not included here as it is already a significant net gas importer from other countries in the table and its exports will decline further.
Source: BP (2021a), pp.44–45.

Table 2: Pipeline gas and LNG exporting companies which were the largest suppliers to Europe in 2020

COUNTRY	PIPELINE GAS	LNG
Russia	Gazprom	Yamal LNG
Norway	Equinor	Equinor, Neptune Energy, Total
Algeria	Sonatrach	Sonatrach
Qatar		Qatar Energy (formerly Qatar Petroleum)
Nigeria		Nigeria LNG
United States*		Cameron LNG, Freeport LNG, Sabine Pass, Corpus Christi, Elba Island, Cove Point.

*US LNG cargos can be delivered to a wide range of destinations in Europe, Asia, and the Americas.
Source: GIIGNL (2021a), pp.10–17.

UNFCCC and IEA data

There is very little publicly available detailed data on methane emissions from individual fossil fuels on a national basis.[57] Two major sources of data are the United Nations Framework Convention on Climate Change (UNFCCC) and the International Energy Agency's (IEA) Methane Tracker.[58]

[57] For global data from all sources see Appendix 2.
[58] UNFCCC (2021), IEA Methane Tracker (2021). Two additional sources are Global Methane Initiative (GMI) https://www.globalmethane.org/methane-emissions-data.aspx and the Global Carbon Project https://www.globalcarbonproject.org/methanebudget/.

The UNFCCC data for these countries can be divided into two groups: the Annex 1 countries – the US, Russia, and Norway – which are required to make annual submissions; and the non-Annex 1 countries – Algeria, Nigeria, and Qatar – for which data is from the 2000s or earlier and lacking in detail.

For the Annex 1 countries, the way in which UNFCCC data are reported is different for each country. This arises from the detailed sectoral classification devised for reporting of GHGs and the discretion of governments as to whether emissions are reported by sector (oil, gas, and coal) or by activity (flaring, venting, or other fugitives). There is no consistency and no detail relating to the methodologies used, which might give clues to the accuracy of the estimates, but the advantage is the long time series for each country. Appendix 4 contains what are judged to be the most relevant and available UNFCCC 2010–2019 data on emissions for the gas sectors of the US, Russia, and Norway. UNFCCC data for the three non-Annex 1 countries are included in Section 4.

Table 3 shows methane emissions data for the six countries from the IEA's Methane Tracker website. The advantage of the Tracker data is that they are accessible, compiled using a common methodology, and updated regularly. Another advantage is the classifications, which include both oil and gas. But the classification is different to many other data sets (liquefaction and LNG shipping are included in the downstream) and the methodology which the Agency uses also raises questions.[59]

Table 3: Methane emissions of six major natural gas and LNG exporters to Europe, 2020 (thousand tons)*

	Norway			Russia			Algeria			Nigeria			Qatar			US		
METHANE:	F	V	IF	F	V	IF	F	V	IF	F	V	IF	F	V	IF	F	V	IF
Onshore Conventional Gas				1463	3272		182	406		81	181		4	9		116	260	
Offshore Gas	3	8		28	62					19	42		170	380		12	27	
Onshore Conventional Oil				277	3071	1023	35	383	494	20	216	113	6	70	24	94	1042	99
Offshore Oil	2	20		9	103	51				24	264	145	19	213	18	15	170	31
Unconventional Oil																191	2116	427
Unconventional Gas							5	11								1673	3743	
Downstream gas				1321	730		107	59		64	35		85	47		1438	794	
Downstream oil				2	10			1			1					5	31	
TOTAL (*)	34 (0.2)			13953 (12.1)			1772 (12.4)			1202 (9.4)			1046 (4.7)			12286 (8.3)		

F = fugitive, V = Vented, IF = Incomplete Flaring, Blank indicates less than 1000t *methane intensity in tons of methane emitted per thousand tons oil equivalent produced

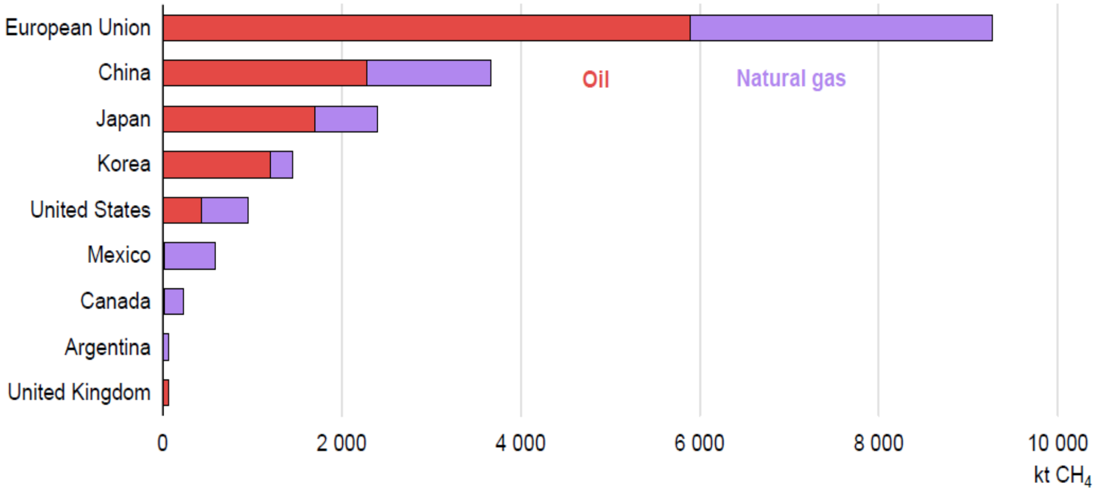
Source: IEA Methane Tracker (2021), accessed 1 November 2021.

Natural gas flaring efficiency

However, neither the UNFCCC nor the IEA data relate to the principal focus in this paper, which is emissions from exports of natural gas and LNG from individual countries and supply chains. Figure 5 shows IEA estimates of methane emissions associated with imported oil and gas for the major global gas importing countries. For the EU and Asian countries, methane emissions from imported oil are greater than those from natural gas. In one respect this is not surprising given that for the EU and Japan, oil import volumes are roughly twice those of pipeline gas or LNG (for China, oil imports are five times larger). But it raises the important issue of methane emissions from the oil sector, taking into account that some of the natural gas imports may have been produced in association with oil.

[59] IEA Methane Tracker (2021) 'Understanding Our Estimates'. For example the Tracker has a category of 'satellite-detected large emitters' (not included in Table 3) which only shows data for Russia and Algeria although large emissions have been detected by satellites from both the US Permian and Appalachian basins. The explanation is apparently that these emissions from the US basins are shown in other categories.

Figure 5: Methane emissions associated with imported oil and gas to selected countries, 2020



Source: IEA, (2021), Figure 3.1, p.33

In 2021, the IEA reduced its estimate of average flaring efficiency to from 98 per cent to 92 per cent, which meant that flaring resulted in emissions of more than 500 mt CO_2e in 2020.[60] Satellite data from Capterio's FlareIntel Portal suggests that for individual countries, the combustion rate for flares may be closer to 90 per cent.[61] If 8–10 per cent of flared gas is vented methane, this results in a much higher level of equivalent carbon dioxide emissions.

Table 4: Flared volumes from major gas exporters to Europe 2016–2020* (bcm)

	2016	2017	2018	2019	2020
Russia	22.37	19.92	21.28	23.21	24.88
United States	8.86	9.48	14.07	17.29	11.81
Algeria	9.10	8.80	9.01	9.34	9.32
Nigeria	7.31	7.65	7.44	7.83	7.20
Qatar	1.08	1.03	1.00	1.34	1.01
Rest of World	9.58	9.15	8.08	8.73	8.81

*Norwegian flaring is too small to be itemized separately by the GGFR but is included in Table 5 below. Russia, the US, Algeria, and Nigeria are among the top seven highest flaring nations in the GGFR study.
Source: World Bank (2021), p.12.

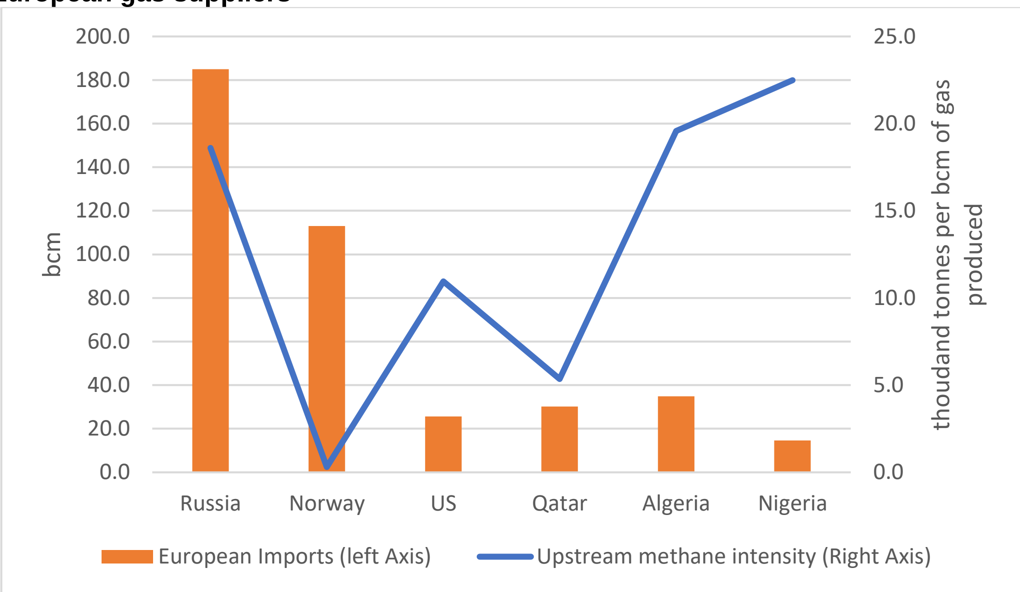
4. Gas and LNG export supply chains of the six major gas and LNG major suppliers to Europe

Figure 6 shows the exports of the six major gas suppliers to Europe and the upstream methane intensity of their oil and natural gas production.

[60] IEA WEO (2021), p.76.
[61] Capterio (2020). Capterio has an internet site – Flareintel – which allows a country by country, asset by asset, satellite measurement of flares.

The intensity figures include only emissions from oil and natural gas production. These *production* intensity calculations do not equate to pipeline gas or LNG *export* intensity.[62] For export intensity it is necessary to calculate emissions from specific export supply chains. Attempts to attribute standard or generalized factors to all LNG exports[63], while understandable in view of the lack of data, fail to recognize this. This section sets out the different export supply chains of the six exporters and the estimates which are needed to calculate their emissions. It focuses on the supply chain segments up to the border of the importing country as this author takes the view that – unless the gas or LNG is being delivered to a very limited number of customers (and sites) – gas deliveries within the importing country can only be credibly tracked, and therefore their emissions measured, by buyers or national regulators.[64]

Figure 6: Natural gas exports to Europe and upstream oil and gas methane intensity of the six major European gas suppliers



Sources: Production from BP (2021a), emissions from Table 3.

Norway

Norway is the second-largest exporter of gas to Europe with several pipeline systems delivering to the UK and continental Europe from oil and natural gas fields on its continental shelf, as well as from a liquefaction facility delivering LNG to both European and global destinations. Gas production on the Norwegian Continental Shelf (NCS) has averaged 114 bcm over the period 2015–2020.[65] Equinor directly owned (or had equity stakes in) more than (roughly) one third of the natural gas which was produced in 2020, but operated and marketed 70–75 per cent of production.[66] Domestic Norwegian gas demand in 2020 was 4.4 bcm compared to pipeline exports of 106.9 bcm, and LNG exports of 4.3 bcm (of which 0.2 bcm was exported outside Europe).[67]

[62] For definitions of the three segments of the supply chain see Section 1. It could be argued that the intensity figures should include only emissions from natural gas, and the emissions from oil production should be reported separately. But since natural gas which is co-produced with oil is included in natural gas production it seems logical to include emissions from both.
[63] For example Swanson and Levin (2020).
[64] Equinor (2021), Roman-White (2021a) and (2021b), GIIGNL (2021b) all attempt a full life cycle analysis including emissions within the importing country.
[65] Equinor (2021), p.2.
[66] Equinor (2020), p.34.
[67] BP (2021a), p.38,44, and 45. In October 2020, the Norwegian LNG plant on Melkoya Island (near Hammerfest) was shut down due to a fire and had not yet reopened at the time of writing.

Table 5: Emissions from Norwegian upstream oil and gas extraction (mtCO_2e)

	2018	2019	2020
CO_2	14.7	14.5	14.3
Methane	0.5	0.5	0.5
Total GHGs	**14.8**	**14.6**	**14.4**
Combustion*	12.7	12.6	12.0
Flaring	0.9	0.8	0.7
Venting	0.2	0.2	0.2
Other fugitive	0.3	0.3	0.2
	14.1	13.9	13.2

*Combustion refers to use of hydrocarbons for power generation and to drive compressors, pumps, and engines.
Notes: All Norwegian statistics use a GWP of 25 to convert tons of methane to CO_2e.
Sources: Statistics Norway; Hall (2020), p.3 and 6.

Norway has by far the most detailed statistics and definitions of GHG emissions from oil and gas of any country under consideration in this study. There are taxes on combusted gas (and diesel) and on vented and fugitive methane emissions from offshore oil and gas installations.[68] Table 5 shows estimates of methane and CO_2 emissions from oil and gas extraction and activity.[69] In addition to these data, the Norwegian Petroleum Directorate's Diskos portal makes it possible to access emissions data by installation, field, and terminal, and by fuel, flaring, and cold venting.[70] There are further details of how emissions are calculated and reported in the Norwegian national inventory report to the UNFCCC.[71] A 2019 study of 13 aircraft surveys of 21 offshore oil and gas fields (satellites cannot observe emissions from offshore operations), found methane loss rates of 0.003–1.3 per cent of gas production.[72] These were significantly lower than both previous (2016) estimates from Norwegian fields and lower than most estimates of production from other countries.[73]

Map 1 shows the routes of Norwegian gas exports to continental Europe via pipeline systems, most of which flow via terminals on the Norwegian mainland (Nyhamna Kollsnes, and Kasto) to receiving terminals in Germany (Emden and Dornum), Belgium (Zeebrugge), France (Dunkerque), and the UK (St Fergus and Easington). The main gas and condensate export pipelines are:[74]

- to continental Europe: Europipe, Franpipe, Statpipe, Norpipe, Zeepipe (mostly via the Draupner offshore platform).
- to the UK: Versterled, Tampen link, Langeled, Utsira High[75].

[68] See the commentary on Norway in https://www.iea.org/reports/methane-tracker-2020/improving-methane-data
[69] Statistics Norway (2021), (Code O8940) https://www.ssb.no/en/statbank/table/08940/tableViewLayout1/. A different estimate of oil and gas extraction, Code 09288, includes service activities and transport via pipelines.
[70] Norwegian Petroleum Directorate (2021).
[71] Norwegian Environment Agency (2020), especially pp.136–166.
[72] Foulds et al. (2021). This wide range 'is driven largely by field-level production volumes with high-producing fields displaying proportionately lower emission rates'.
[73] Ibid.
[74] These are the main export pipelines, others provide linkages and divide gas flows between the different markets (including landing gas in Norway). Details of the pipelines, processing plants, and receiving terminals operated by the Norwegian pipeline company Gassco can be found on the company's website https://www.gassco.no/en/our-activities/pipelines-and-platforms/.
[75] Utsira High (not on Map 1) is a pipeline between the Edvard Grieg field and the SAGE pipeline system.

From the data provided in the sources noted above it would be possible to track emissions from the fields to the Norwegian terminals although:

- the composition of gas which is flared – in other words the degree of combustion efficiency which determines what proportion of the flare is carbon dioxide and what remains unburned and is therefore methane – is not known.
- many NCS fields co-produce oil and gas, and gas and condensate (liquids), and the shares of gas and oil produced are not separately reported.[76] But even if this information was available, to specify emissions from gas production and exports would require a degree of arbitrary allocation of emissions between oil and gas streams.

Gassco, which operates all the export pipelines and terminals, provides emission estimates for what it calls 'the company's own plants' and assumes there are no emissions from the subsea pipelines from the terminals to the continental European and UK landing points.[77]

It is not possible to attribute emissions from individual fields and terminals to specific landing points in continental Europe and the UK, because the NCS network is run as a flexible export system where flows to different markets are continuously optimized via different terminals and platforms. Equinor calculates emissions from its 2020 piped European gas exports as follows:[78]

- Exploration, development, and production: GHG intensity 1.3gCO_2e/MJ, methane intensity 0.01 per cent.
- Processing and transport: GHG intensity 0.3gCO_2e/MJ, methane intensity <0.01 per cent.
- For both these segments the share of carbon dioxide in total GHG emissions from pipeline gas was 96.7 per cent and the share of methane was 2.7 per cent.

In 2019, Equinor's LNG export terminal on Melkoya Island (not shown on Map 1) flared 62.2 million cubic metres (mcm) and used 264 mcm of fuel gas (as well as 97 thousand litres of diesel fuel).[79] Equinor calculates its emissions from the different segments as:[80]

- Production, pipeline, processing, and liquefaction: GHG intensity 3.8gCO_2e/MJ, methane intensity 0.01 per cent.
- Transport (LNG shipping): GHG intensity 2.9gCO_2e/MJ, methane intensity <0.21 per cent.
- For both these segments the share of carbon dioxide in total GHG emissions from the LNG facility was 98.9 per cent and the share of methane was 1.1 per cent.

It is not clear, particularly for pipeline gas exports, how Equinor has allocated emission intensities between gas which is associated with oil production and dry gas production, the assumption being that these would be similar. The overall conclusion is that emissions from Norwegian gas exports to European destinations are extremely low, much lower than those of other exporters, which is borne out by the data in Figure 6, Table 5, and Foulds et al. (2021). The data is extremely detailed compared with all other exporters, but more precise estimates of emissions from exports to individual markets are not possible because of the comingling of gas at the terminals and platforms.

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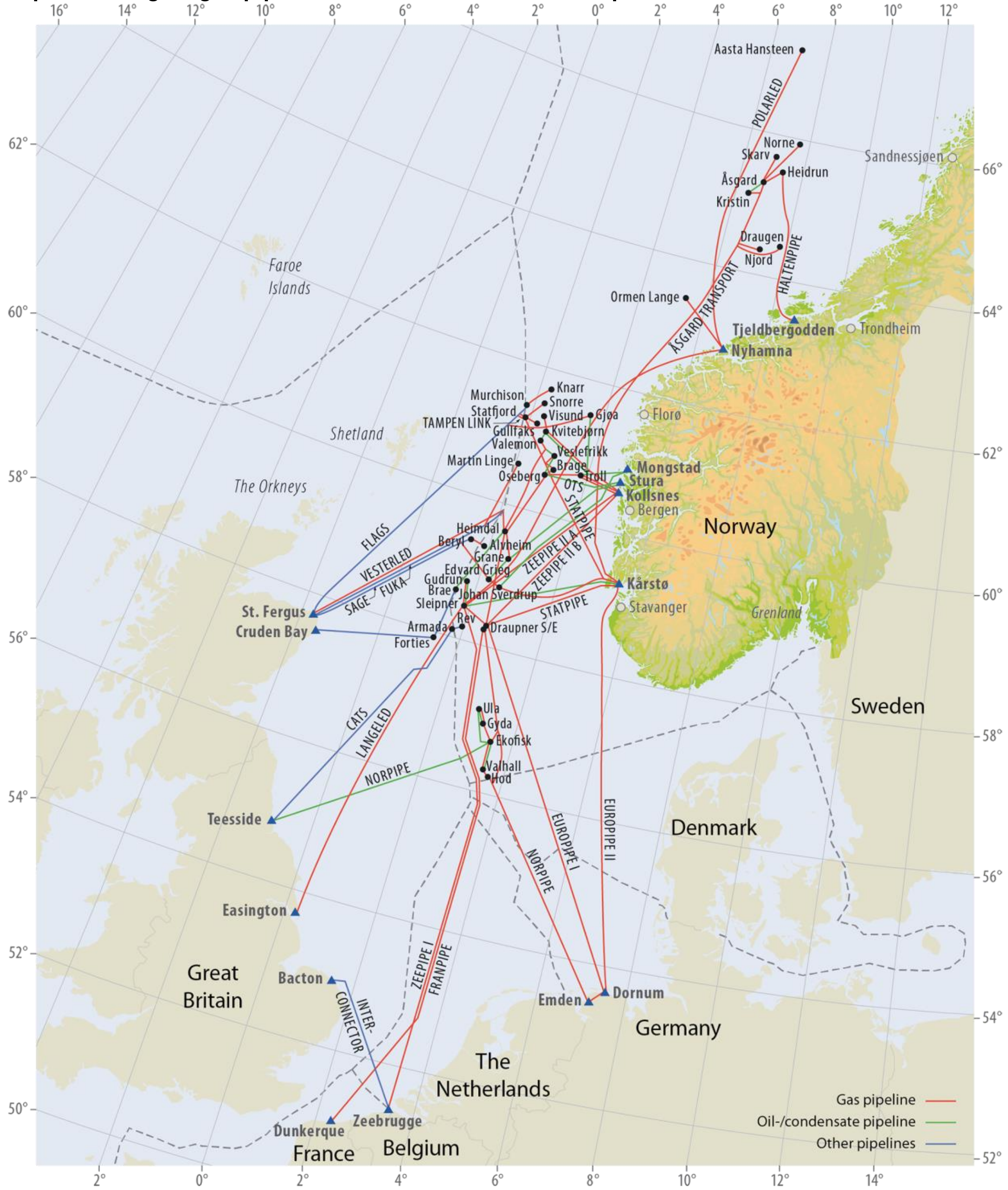
[76] Equinor (2020), pp. 35–7 gives production from individual fields in mboe/day and designates them as oil, oil and gas, or gas and condensate fields.
[77] Gassco (2020), p.24–7.
[78] Equinor (2021), p.4. Equinor also has data for emissions from the markets into which it sells gas (transmission, storage, and distribution) and intensities for deliveries to Central Europe and Germany.
[79] Diskos Reports: https://portal.diskos.cgg.com/prod-report-module/. The most recent full year of the plant's operation was 2019; it was closed following a serious fire in September 2020 and will not reopen until 2022. The plant captures and stores carbon dioxide in deeper horizons of the fields which supply the gas (Snohvit and Askeladd).
[80] Equinor (2021), p.8.

Map 1: Norwegian gas pipeline routes to continental Europe and the UK



Source: Norwegian Petroleum Directorate

Russian Federation

Russian gas is exported by pipeline only by Gazprom which has a monopoly, and LNG is exported by Gazprom (in the east of the country[81]) and by Novatek and the partners of Yamal LNG in the north, from where LNG can flow to both the Atlantic and Pacific Basin markets. Ahead of many other countries,

[81] Gazprom is a majority shareholder and operator of Sakhalin LNG which exports liquefied natural gas to Pacific Basin countries.

Russia designated methane as a pollutant in 1989, with measurement and verification procedures from the Federal Agency on Technical Regulation and Metrology, and fees payable for releases.[82]

Gazprom's pipeline gas supplies to Europe

Gazprom's pipeline gas flows through four major pipeline corridors to European countries: Nord Stream, Yamal–Europe, Ukraine (Brotherhood and Soyuz) and the Black Sea (Blue Stream and TurkStream) pipelines. Russian gas currently enters the EU at the border of 11 member states: Finland, Germany, Poland (3 entry points), Slovakia, Hungary, Romania, Bulgaria, Finland, Estonia, Lithuania, and Latvia, as well as two locations in Turkey.[83] It will be important – and for some locations relatively complicated – to trace back the origin of the gas delivered to each of these borders to the fields where it is produced.

Maps 2 and 3 show the routes in Europe from fields in north-west Siberia and the Yamal Peninsula which provide deliveries through Nord Stream and Yamal–Europe (via Belarus) to north-west and central European borders (Map 2).[84] The capacity of the Nord Stream and Yamal–Europe pipeline systems is 135–144 bcm, all of which is assumed to be delivered to Europe from the largely 'dry' gas fields in north and north-west Siberia.[85] The methane content of these fields is extremely high with very little condensate, which would suggest that flaring of gas would be minimal.[86] However, small flared volumes have been observed by satellites[87] and could increase as gas supplies with a larger liquids fraction from the deeper layers of the Urengoy and Yamburg fields are developed.

From Gazprom pipeline maps, the Ukraine system can be assumed to receive gas from fields around Novy Urengoy via Surgut, Tyumen, and Petrovsk; some of this gas could originate from oil fields where flaring and venting could be a significant issue.[88] Under the transit agreement signed at the end of 2019, Gazprom has to ship or pay for 40 bcm of gas annually through the Ukrainian network (although it has the opportunity to purchase additional capacity should it wish to do so) until the end of 2024, when the agreement can be extended for a further 10 years.[89]

The gas which feeds the Blue Stream/Turkish Stream pipelines is from production at the Orenburg field complex and from north-west Siberia (around the Urengoy field) that used to be exported via Ukraine (Map 3).[90] Some of that gas could be associated with oil production – which would allow for the possibility of flaring and venting. It seems likely that, as production from those fields has been in decline for several years, Blue Stream and TurkStream pipelines will eventually be supplied by production from Yamal Peninsula fields.[91]

Gazprom provides a significant volume of information about its emissions by greenhouse gas, sector and type of emission (details can be found in Appendix 5) which shows emissions of just over 1 mt in 2020, of which the majority are from the pipeline network.[92] This represents a very low methane intensity given the volumes which are produced and transported through the Gazprom network. Where gas

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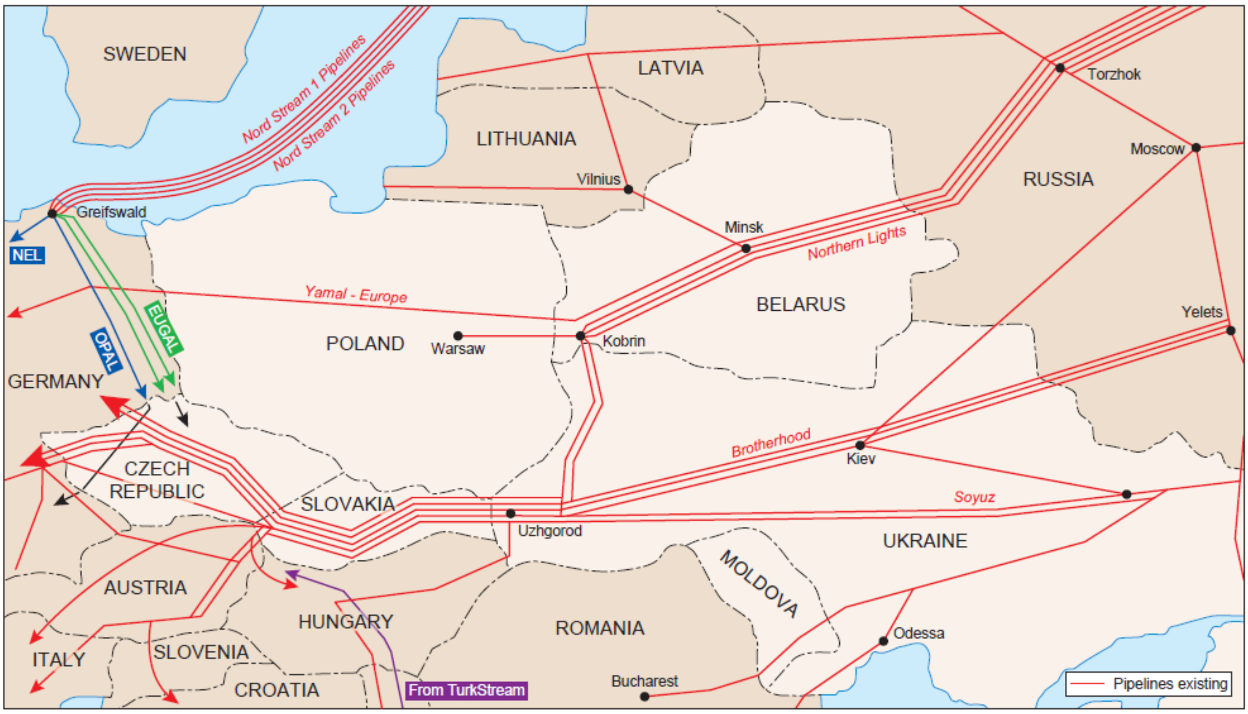
[82] Romanov (2020).
[83] There are other entry points in Romania and Estonia which are currently not operating. For details see Sharples (2018) and Mitrova et al. (2019).
[84] For maps which show the routes from the gas fields see: https://www.gazprom.com/projects/yamal-europe/, https://www.gazprom.com/projects/srto-torzhok/, and https://www.gazprom.com/projects/bovanenkovo-ukhta/.
[85] These systems are the Bovanenko–Ukhta pipelines, Ukhta–Torzhok, and SRTO–Torzhok lines with onward pipelines from Gryazovets to Vyborg and Ust Luga. It is possible that small volumes could be used locally in NW Russia so that the full capacity does not reach Europe.
[86] Methane accounts for more than 96% of the composition of the major NW Siberian and Yamal Peninsula gas fields, which have very small liquid fractions. Zhabreva (1982), Tables 30 and 31, pp.123–4.
[87] Capterio's Flareintel tool (http://flareintel.com/) registers limited flaring at some fields.
[88] Map of gas projects: https://www.gazprom.com/f/posts/15/301731/map-develop-2019-en.jpg.
[89] This is likely to be part of the bargaining process between the German and US governments and EU regulatory authorities in relation to the certification of Nord Stream 2, see Yafimava (2021) and Yafimava and Fulwood (2021).
[90] Map of gas projects: https://www.gazprom.com/f/posts/15/301731/map-develop-2019-en.jpg Map 3 also shows the route of gas deliveries from Azerbaijan to southern Europe via Turkey.
[91] For details of production decline by field see Yermakov (2021), Figure 16, p.20.
[92] This is data for Gazprom's gas activities as the only exporter of pipeline gas. Data in Table 4 and Figure 6 are for the Russian Federation and include emissions from all oil and gas production.

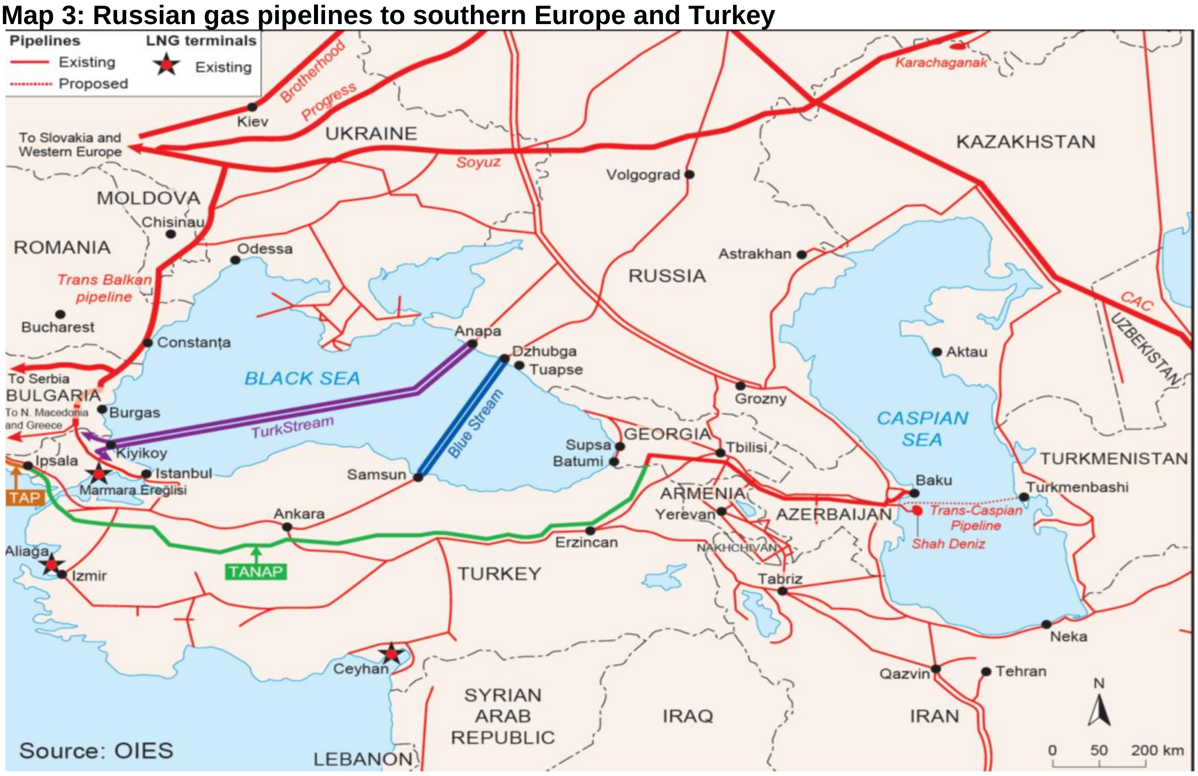
transits via Ukraine and Belarus, these governments and companies would be required to provide estimates of emissions on their territories.[93]

Map 2: Russian gas pipelines to north-west Europe



Source: OIES

Map 3: Russian gas pipelines to southern Europe and Turkey



Source: OIES

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[93] Gazprom owns and operates the Belarusian transmission network.

Yamal LNG

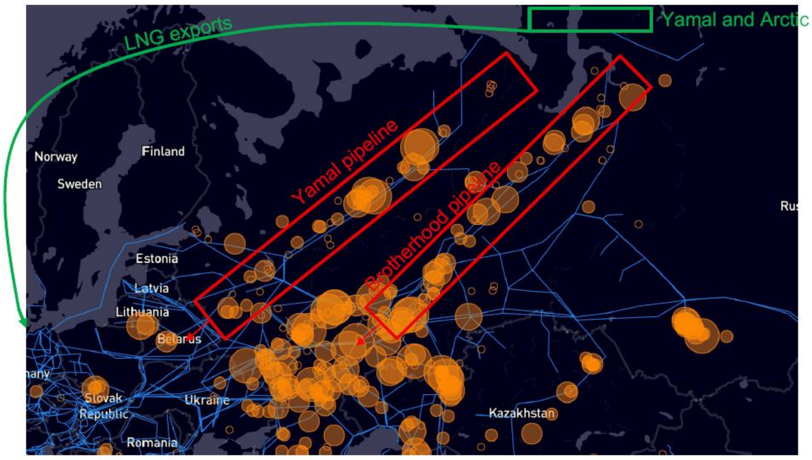
Europe also imports Russian LNG, although on a much smaller scale, from the Yamal LNG project. The gas for this project is supplied from the South Tambey field on the Yamal Peninsula, which is a relatively dry gas field with 13 mt of liquid reserves.[94] Novatek's 2020 methane emissions were just under 8500 tonnes of which 90 per cent were from production (see Appendix 5).

This brief description of Russian gas export supply chains makes clear that it will be necessary to establish separate emission profiles for the different pipeline gas streams reaching Europe through: the Yamal–Europe and Nord Stream pipelines, the Ukrainian network, the Blue Stream and Turkstream pipelines; and the supply chain from Yamal LNG.

Figure 7 shows satellite observations by Kayrros for Russian pipelines and Arctic LNG terminals. It is mostly not possible to obtain satellite observations of methane emissions from Russian gas fields in Arctic regions due to a covering of snow for a large part of the year. The majority of satellite observations have been from the transportation sector where, in 2019–2020, Kayrros detected 13 events along the Yamal pipeline and 33 events along the Brotherhood pipeline, some of which are shown in Figure 7.[95]

These observations were cross-checked with Gazprom which confirmed them as consistent with the data that it has reported (see Appendix 5), connected with (mainly) releases from compressor station maintenance and one unplanned release.[96] The emissions in Figure 7 can be represented as super-emitters, raising the question of whether smaller emissions may be unrecorded. Gazprom's reported emissions from production are extremely low, which independent verification would be required to corroborate. In addition, the extent to which data in Appendix 5 have been measured empirically or calculated from standard engineering emission factors is not clear but nevertheless, compared with many global counterparts, the data provided by the two Russian companies is detailed, transparent and verified.

Figure 7: Satellite observations of methane emissions from Russian gas pipelines and LNG terminals 2019–2020



Source: Kayrros

United States

Emissions from US LNG exports are the most complicated of the six countries under consideration to estimate with any accuracy. Attempts to calculate emissions from US LNG exports have illustrated these complexities.[97] The first problem is that in the US, unlike any other country, gas is produced from hundreds of thousands of wells in geological basins – rather than from named individual gas fields.

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[94] Novatek (2020), p.36 and 41–2.
[95] Personal communication with Kayrros.
[96] Romanov (2020).
[97] Gan et al. (2020), ICF (2020), Roman-White et al. (2019).

These basins produce conventional and unconventional gas, some of which is associated with oil production, or which is principally gas but with liquid fractions. Gas which is produced is gathered and may need to be compressed before it reaches a processing plant, a process known in the US as 'gathering and boosting'. Gas is then processed and transported (with additional compression) and may also be stored before it reaches the liquefaction terminal.[98]

The most widely used set of emissions data are from the US Environmental Protection Agency's (EPA) Greenhouse Gas Reporting Programme (GHGRP).[99] A number of academic and NGO studies based both on detailed bottom-up measurements of specific basins and groups of fields, as well as satellite observations and aircraft overflight measurements, have reached estimates several times higher than those of the EPA.[100] An attempt to identify why the EPA persistently underestimates methane emissions concluded that

> ' … venting and multifunction-related emissions from tanks and other equipment leaks are the largest contributors to divergence ... '.[101]

Similar problems have been encountered in relation to US flaring data, with basin-focused estimates suggesting that emissions may be a factor of two higher than EPA data suggest.[102] Aerial surveys by the Environmental Defense Fund found that malfunctioning and unlit flares in the Permian Basin resulted in methane emissions 3.5 times larger than EPA estimates.[103]

Table 6 shows Kayrros data on average methane emissions and intensity from the Permian, Anadarko, and Marcellus Basins for 2019–2020. It shows that emissions from the different basins are substantially different, with the intensity of the Anadarko being twice that of the Marcellus. Kayrros satellite observations show that methane observations are concentrated in the production areas where super-emitters continue to be observed; there are no significant observations from gas pipelines or from LNG plants.

Table 6: Methane emissions and intensity from satellite observations of three major US oil and gas producing basins (average 2019–2020)

BASIN	EMISSIONS (mt methane)	INTENSITY (kg methane per boe)
Permian	2.34	0.89
Anadarko	1.01	1.53
Marcellus	1.66	0.75

Source: Kayrros

Methodology and data for calculating methane (and other greenhouse gas) emissions from US LNG exports involve extremely complex measurement which cannot be exact because of the inability to trace the gas molecules from the cargo back though its journey to the wellhead. A set of complex assumptions needs to be made for each stage of the supply chain, which is described in a study of emissions from Cheniere's 2018 LNG cargos (see Section 5).[104]

There are six operating US export terminals with multiple trains, and two further terminals are under construction.[105] It is likely that each terminal, and possibly each train, will have a different emission footprint. The Cheniere study (Section 5 below) provides a life cycle emission estimate for its 2018

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[98] Roman-White et al. (2019), Exhibits 5.1–5.5 give details of these processes and CO_2 and methane emissions for 10 basins. Exhibits 5.7–5.10 provide parameters for liquefaction, loading, and unloading of cargos, ocean transportation, and regasification.
[99] EPA (2021).
[100] For example: Alvarez et al. (2018), Howarth (2019).
[101] Rutherford et al. (2020).
[102] See Kleinberg (2019) for a focused discussion on the Bakken oilfield flares.
[103] EDF (2021), see also Kleinberg (2021 forthcoming).
[104] Roman-White et al. (2021a) and (2021b).
[105] Sabine Pass, Freeport LNG, Cameron LNG, Corpus Christi, Cove Point, and Elba Island are operational; Golden Pass and Calcasieu Pass are under construction.

supplier-specific supply chain providing gas to its own Sabine Pass LNG terminal. For the 2018 supply chain, 58 per cent of gas was purchased from a known supplier, with the remaining 42 per cent coming from a gas trading entity and modelled using assumptions.[106] By contrast, exporting companies which purchase all their gas from traders, and pay for it to be transported to a terminal with which they have a tolling agreement, may have very little visibility about the details of the supply chain and its emissions prior to the loading of the LNG cargo.

Of potential future relevance is the Methane Fee legislation introduced by the Biden Administration as part of the 'Build Back Better' programme.[107] Analysis of a possible methane fee suggests that substantial emission reductions may be possible with relatively modest fees of $1000–1500/t methane.[108]

Algeria, Qatar and Nigeria

There is far less detailed national data for Algeria, Nigeria, and Qatar on their natural gas balances or their emissions, compared with the three countries discussed above. But as members of the Gas Exporting Countries Forum, they can be assumed to contribute the data in Table 7 to its Statistical Bulletin.

These countries have very significant gas production, although Algeria and Nigeria reinject between a quarter and a third in order to increase recovery from their oil fields. In these two countries, flaring is also significant and the volumes in Table 7 are different (and for Algeria very much lower) than for the corresponding years in Table 4.

As noted Table 2, LNG exports are the responsibility of a single government-owned company in each country: Sonatrach, Qatar Energy, and Nigeria LNG. But these companies are in joint ventures with international oil and gas companies, some of which export their own share of the LNG. This is a potential problem because of companies reporting emissions from their equity share (see Table 8 in relation to Qatar), rather than for an entire asset or segment of the chain although it is not clear why, at least in terms of intensity, emissions from an equity share should be different between joint venture partners.

[106] Roman-White et al. (2021a) and (2021b).
[107] Methane Emissions Reduction Act of 2021, https://www.congress.gov/bill/117th-congress/house-bill/4084.
[108] Prest (2021). At the time of writing the Bill was being debated in Congress.

Table 7: Gas production and losses from Algeria, Qatar, and Nigeria, 2015–2020 (bcm)

	2015	2016	2017	2018	2019	2020
ALGERIA						
Gross Production	183.8	189.1	188.7	183.6	175.4	168.4
Marketed Production	84.6	95	96.6	97.5	90	84.8
Reinjection	77.2	70.1	66.9	61.1	60.3	60
Flaring	3.5	3.3	3	2.9	2.7	3.2
Shrinkage	18.7	20.8	22.2	22.1	22.3	20.4
QATAR						
Gross Production	175.9	172.2	171.4	175.4	181.3	21.5
Marketed Production	170.1	166.1	165.4	170	176.3	205.7
Reinjection	2.5	2.7	2.7	2.3	2.5	2.2
Flaring	0.7	0.7	0.7	0.6	0.7	1.1
Other Losses	2.6	2.6	2.6	2.5	1.8	2.5
NIGERIA						
Gross Production	85.2	767.8	79.5	80.3	81.1	77.2
Marketed Production	45.2	42	45.8	47	47.7	47.9
Reinjection	21	19.9	21.7	21.5	22.3	19.8
Flaring	9.7	8.2	8.1	8	6.9	5.5
Other Losses	9.4	6.7	3.9	3.8	4.2	4.1

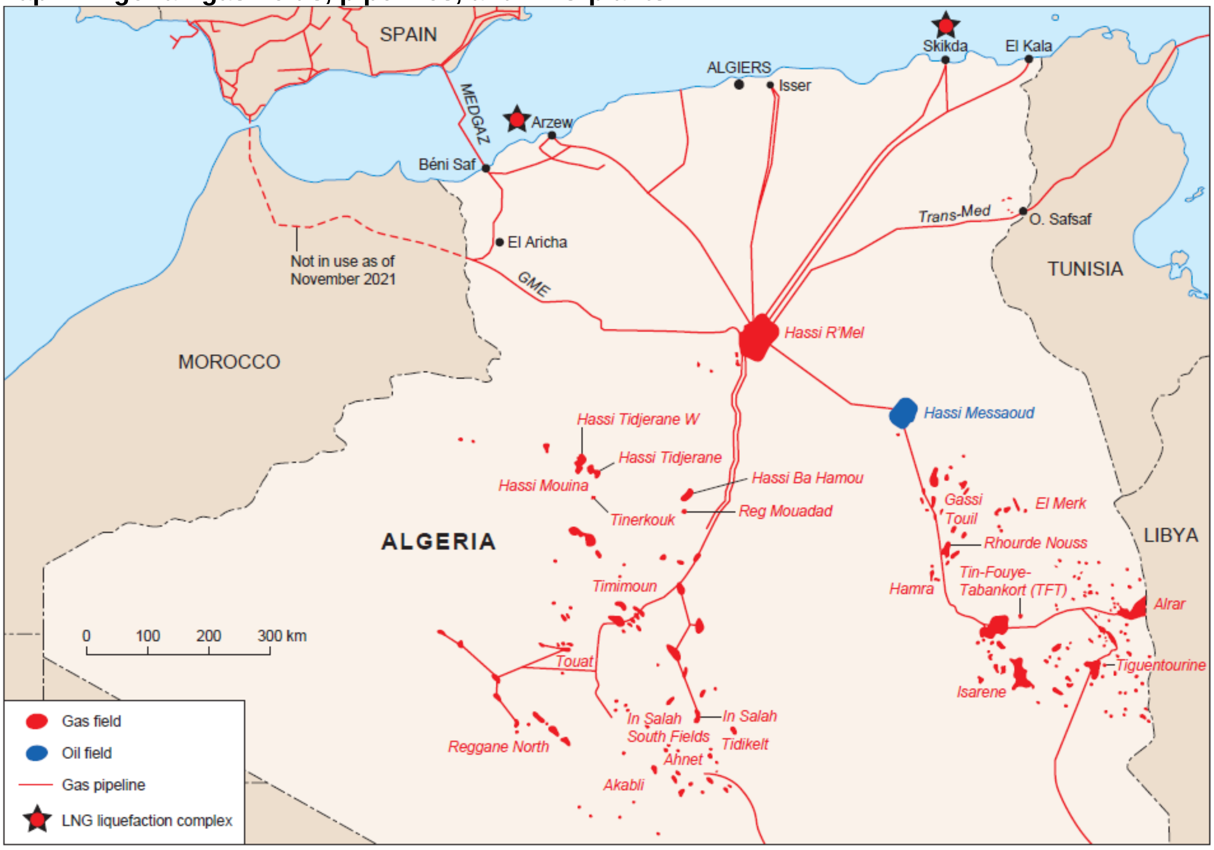
Source: GECF (2021), p. 47,71, and 75.

Algeria

The only entries in the UNFCCC database for GHG and for methane emissions are for 2000, with comparative data for 1994.[109] Total methane emissions for 2000 were 1568 kt (almost 30 per cent of Algeria's total reported GHG emissions), of which 1001 kt were from the energy sector, almost double the 515 kt reported for 1994.

[109] UNFCCC (2021).

Map 4: Algerian gas fields, pipelines, and LNG plants



Source: OIES adapted from Sonatrach's Oil and Gas Map of Algeria, 2018

Natural gas is produced from a multitude of fields located in the south-eastern and south-western regions of Algeria (see Map 4). The bulk of the gas is produced from about a dozen fields, with the largest gas field by far being Hassi R'mel. Two systems of gas pipelines supply the industrial zones of Arzew (western Algeria) and Skikda (eastern Algeria), where the two LNG complexes are located. Exports by cross-border gas pipelines are also supplied from Hassi R'mel through the Trans-Mediterranean (TransMed) gas pipeline to Italy via Tunisia, and the Gaz Maghreb Europe (GME) and Medgaz pipelines to Spain.[110] There are two liquefaction complexes at Arzew and Skikda. Twelve of the trains at Arzew date from the late 1970s and early 1980s; additional trains at Skikda and Arzew were commissioned in 2013 and 2014.[111]

The figure for 'shrinkage' in Table 7 is remarkable. This refers to the reduction in the volume of gas due to the extraction of natural gas liquids at several liquids-rich fields. However, a figure exceeding 10 per cent of gross production is unprecedented and invites speculation as to whether this may include losses which are not separately itemized.

Figure 8 shows Kayrros' satellite observations from Algerian producing fields – including 200,000 tons per year at Hassi R'Mel – but none from pipelines or liquefaction plants. Satellite data from Capterio show very large volumes of gas being flared, particularly at Hassi Messaoud (2.3 bcm in 2020), with flaring efficiency of around (and possibly below) 90 per cent.[112]

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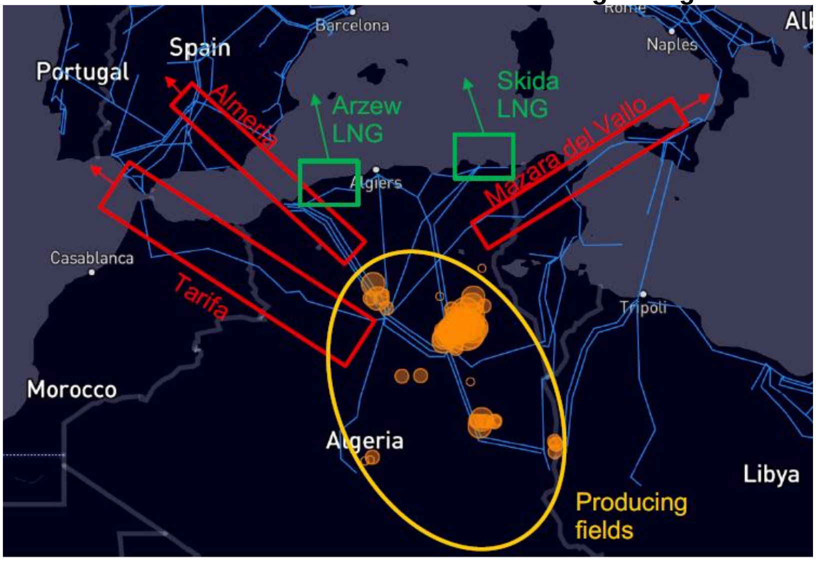
[110] Prior to November 2021 the GME pipeline delivered gas to Spain via Morocco, but the two countries failed to agree an extension of the transit contract and GME was connected to Medgaz with a capacity expansion.
[111] GIIGNL (2021a), p.41.
[112] Capterio (2021).

Figure 8: Satellite observations of methane emissions from Algerian gas fields



Source: Kayrros

All production is transported to Algeria's 'National Gas Dispatching Center' located at Hassi R'Mel, and dispatched from the Hassi R'Mel gas hub to Northern Algeria to supply domestic markets and gas export pipelines and LNG facilities. Production from individual fields is therefore not allocated to specific export markets, and it is not possible to trace the molecules being exported from the fields to the export pipelines or LNG facilities. The first step towards MRV would therefore be an assessment of emissions from production at the different gas and oil fields, combined with assessments of emissions from the domestic and international pipelines and liquefaction plants.

Until very recently there was no sign of any move in this direction, but Sonatrach's 2020 Annual Report states that it:[113]

> 'launched a GHG inventory system up to the [production] site … and put in place a system of measuring, reporting and verification (MRV) of mitigation that will allow the identification and quantification of all significant mitigation actions and estimation of avoided GHG [emissions] … This initiative allows for a strategic planning of the reduction of Sonatrach's carbon footprint.'

While this is a general statement with no data, it demonstrates an awareness of emission issues and the start of a programme of reduction.

Qatar

UNFCCC data are only available for 2007, before completion of the main phase of North Field/LNG expansion, when methane emissions were 168 kt, about 6 per cent of total GHG emissions, with the energy sector accounting for 90 per cent of reported methane emissions.

Compared with other countries, the Qatari export supply chain is relatively simple. The vast majority of gas is produced from the offshore North Field and transported through relatively short pipelines to the Rasgas and Qatargas liquefaction plants.[114] Four of the liquefaction plants were commissioned in the mid to late 1990s; six in the 2000s, and three in 2010–2011.[115] In 2019, Qatar Petroleum inaugurated a carbon dioxide recovery and sequestration facility with an annual capacity of 2.2 mt.[116] In the same year, the government announced the construction of a carbon capture and storage plant which,

[113] Sonatrach (2021), p.79.
[114] Rogers (2019) has a history and description of Qatari LNG exports.
[115] GIIGNL (2021a), p.42.
[116] Qatar Petroleum (2019), p.43.

combined with enhanced oil recovery, will be sequestering 5 mt of carbon dioxide from four new LNG trains due to be onstream by the mid-2020s.[117]

Table 8: Methane emissions and flaring from Qatari LNG operations

GHG Emissions from LNG Facilities (equity basis):*	2015	2016	2017	2018	2019
Scope 1 LNG facilities	22.88	22.23	22.61	22.05	21.30
Scope 1 LNG facilities exported energy	0.04	0.07	0.07	0.09	0.08
Scope 2 LNG facilities	0.42	0.42	0.41	0.42	0.43
Greenhouse Gas Emissions Intensity LNG Facilities**	0.314	0.315	0.310	0.307	0.299
Methane Intensity LNG Facilities (% sweet gas)	0.20	0.22	0.25	0.21	0.19
Flaring LNG facilities***	29,217	26,558	24,442	21,091	16,894
Flaring Intensity LNG****	0.57	0.59	0.54	0.47	0.38

*mt CO_2eq **mtC02eq/mt hydrocarbon production ***MMSCF hydrocarbon flared ****MMSCF hydrocarbon flared/MMSCF sweet gas production %.

Note: mtCO_2eq with a GWP of 25

Source: Qatar Petroleum (2019), Appendix E, p.79.

Data published by Qatar Petroleum (the company was renamed Qatar Energy in October 2021) on emissions from LNG operations are shown in Table 8. The data are difficult to interpret, in particular the reference to 'equity basis' in relation to the Scope 1 and 2 data suggests that they relate only to Qatar Petroleum's share of sales and not to total emissions from the LNG facilities. The intensity data should relate to total emissions from the LNG facilities and (mostly) show that both methane intensity and flaring intensity have declined (although not consistently) over the 2015–2019 period. They provide a good (but not completely clear) guide to emissions from Qatari LNG exports prior to ship loading. Satellite observations of methane emissions would not be possible from Qatar's offshore North Field.

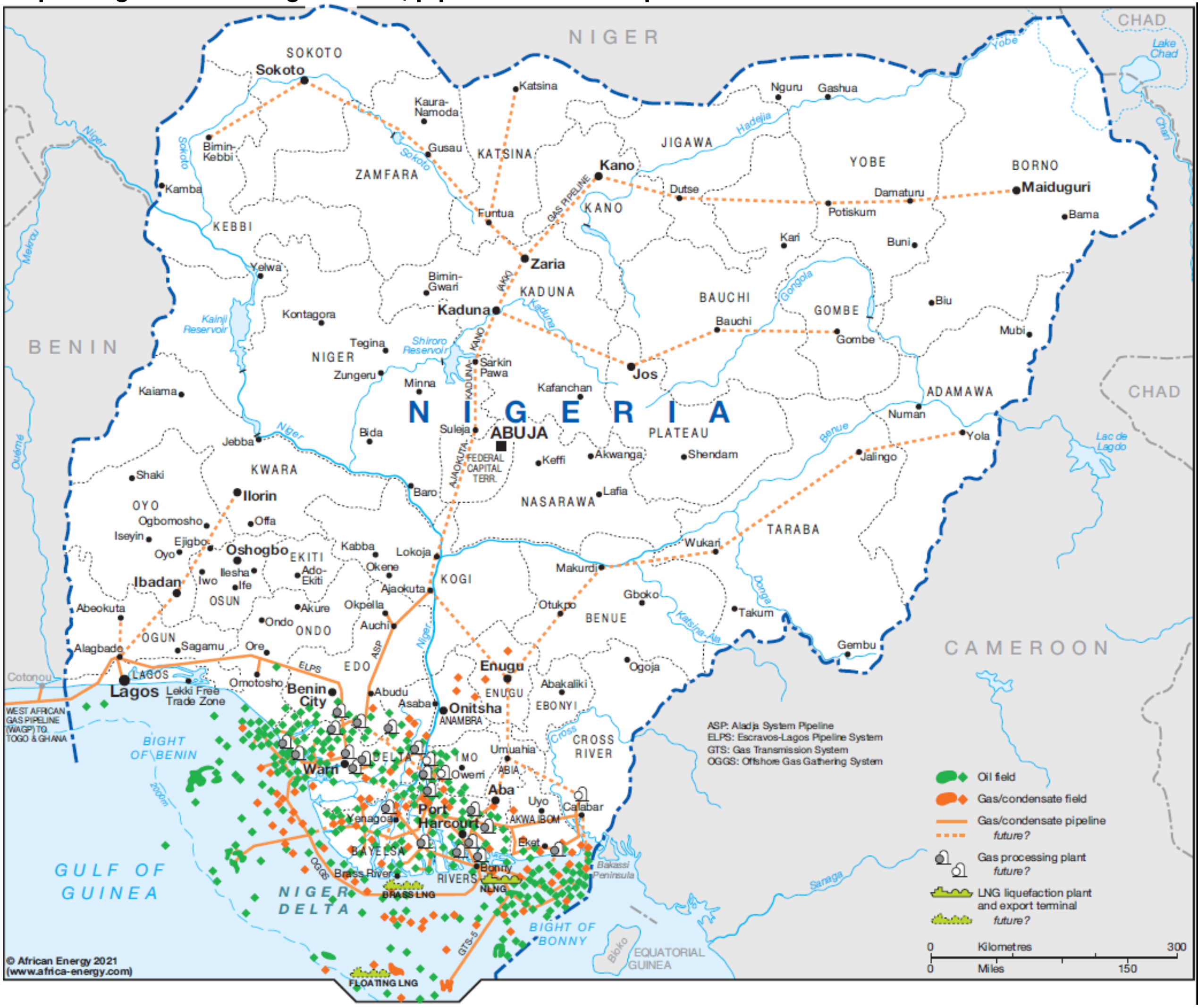
Nigeria[118]

The UNFCCC database has methane emissions data for only two years, 1994 and 2000. National methane emissions in 2000 were 5912 kt, of which the energy sector accounted for 1476 kt or 25 per cent of the total. The agricultural sector was a larger source of reported methane emissions than the energy sector in both 1994 and 2000. In 2000, methane accounted for more than 40 per cent of reported GHG emissions.[119]

With six LNG trains in full operation, the total gas requirement of the company's Bonny Island natural gas liquefaction plant is about 35 bcm/year. Gas is supplied to the NLNG complex through six independent Gas Transmission Systems (GTS), four onshore and two offshore lines. The first two NLNG plants were commissioned in 1999 and 2000, and the remaining four between 2002 and 2006. Gas for the liquefaction plants is produced by the Joint Ventures (JVs) from various concession areas in the Niger Delta – from onshore and offshore fields – and supplied to Nigeria LNG (NLNG) under long-term Gas Supply Agreements (GSAs) with each JV. Map 5 shows the large number of onshore and offshore fields and multiple processing plants, supplying gas to NLNG's liquefaction plants on Bonny Island.

[117] Paraskova (2019).
[118] Paragraph two of this section summarizes text from the NLNG website: https://www.nigerialng.com/operations-strategies/Pages/Gas-Supply.aspx.
[119] UNFCCC (2021).

Map 5: Nigerian oil and gas fields, pipelines and LNG plants



Source: African Energy, November 2021

This brief description and Map 5 illustrate the complexity of tracing gas from fields through different pipelines and processing plants, where supply is comingled before reaching the LNG plants. Therefore, an estimate of average emissions for gas delivered to the LNG plants may be the most realistic initial measurement, ahead of more detailed MRV of gas delivered from individual JVs and the liquefaction plants themselves.

5. Carbon neutral and MRV methodologies for GHG emissions from global LNG trade

This section is a departure from the specific focus on methane emissions and European trade of the previous sections but is strongly related to them. MRV of all greenhouse gas emissions from LNG trade has come into sharp focus with the advent of so-called carbon-neutral cargos, and the creation of new frameworks to increase transparency.

Carbon-neutral LNG

In 2019, the first LNG cargos designated ‘carbon-neutral’ were delivered to Japan, Korea, and India by Shell and JERA. The term ‘carbon’ is misleading since most of these cargos claim to be measuring not just carbon dioxide emissions but also other greenhouse gases (principally methane and nitrous oxide). The term ‘neutral’ in this context means that offsets have been purchased equivalent to the greenhouse gas of the cargo for the full export supply chain from production to end-use.[120] Table 9 shows that up to October 2021, more than 30 cargos of carbon-neutral LNG had been delivered to (mostly) Asian – Japanese and Chinese – destinations.[121] A significant number of these cargos have been delivered by, or for, Shell where the GHG footprint of the entire LNG value chain has been offset by purchasing emission credits from the (mostly) forest projects owned by the company.[122] In Japan, Tokyo Gas established a Carbon-Neutral LNG Buyers Alliance to procure and supply the Alliance companies with carbon-neutral gas.[123] Osaka Gas has a similar group that includes its subsidiary Daiwa Gas and industrial customers.[124]

Table 9. Carbon-neutral LNG cargos, 2019–October 2021

DATE	SELLER	BUYER	DELIVERY
Jun-19	Shell	Tokyo Gas	Japan
Jun-19	Shell	GS Energy	South Korea
Jun-19	JERA	not known	India
March-2020 and November-2020	Shell (2x)	CPC (2x)	Taiwan
Jun-20	Shell (2x)	CNOOC (2x)	China
Oct-20	Total	CNOOC	China
Mar-21	Mitsui	Hokkaido Gas	Japan
Mar-21	Gazprom	Shell	U.K.
Mar-21	RWE	POSCO	South Korea
Apr-21	Mitsubishi/DGI	Toho Gas	Japan
Apr-21	Not known	Pavilion Energy	Singapore
May-21	Cheniere	Shell	Europe
Jun-21	not known	TotalEnergies/OMV	Netherlands (Gate)
Jun-21	Oman LNG	Shell	***
Jul-21	Shell	Osaka Gas	Japan
Jul-21	Novatek	Saibu Gas	Japan*
Jul-21	Shell	Petrochina**	China
Jul-21	Ichthys LNG	Inpex	Japan
Jul-21	Unstated	AES	Dominican Republic
Jul-21	BP	Sempra****	Mexico
Aug-21	Petronas	Shikoku Electric	Japan
Aug-21	ENI	CPC	Taiwan
Aug-21	Inpex	Iruma Gas	Japan***
Sep-21	Inpex	Shizuoka Gas	Japan
Sep-21	Inpex	Toho Gas	Japan
Sep-21	Unstated (source Qatar)	Naturgy	Spain
Sep-21	Petronas	Shenergy (3 cargos)	China***
Sep-21	BP	CPC****	Taiwan
Oct-21	Sakhalin Energy	Toho Gas	Japan
Oct-21	Sakhalin Energy	Toho Gas	Japan
Oct-21	Diamond Gas	Japex	Japan

Sources: RWE (2021), Klass (2021), Pavilion Energy (2021b), Cheniere (2021b), Gate (2021), JERA (2019), Osaka Gas (2021), Pekic (2021), Hashimoto (2021), Shell (2019), Shell (2020a), Shell (2020b), Shell (2021a), Shell (2021b), Total (2020), Hasegawa (2021), BP (2021b), Naturgy (2021), Sakhalin Energy (2021), AES (2021), Reuters (2021).

[120] But in the case of the June 2019 Jera cargo, Scope 3 emissions (emissions within the importing country) only.
[121] It is not possible to be certain about numbers of cargos as there is anecdotal evidence that some have not been reported and it is not clear whether delivery has taken place for some of the contracts which have been announced.
[122] Blanton and Mosis (2021), p.13 state that Shell's transactions are nature-based offsets from the Verra Registry.
[123] Tokyo Gas (2021). The 15 participants of the alliance include Tokyo Gas, Asahi Group Holdings, Isuzu Motors, Olympus Corporation, Sakai Chemical Industry, Duskin, Tamagawa Academy & University, Toshiba Corporation, Toho Titanium, New Otani, Marunouchi Heat Supply, Sumitomo Mitsui Trust Bank, Mitsubishi Estate, Yakult Honsha, and Lumine.
[124] Osaka Gas (2021).

For some listed in Table 9, the origin or buyer of the cargo, or type of offset, has not been disclosed.[125] Few cargos confirmed the volume of gas or emissions, and many of those which did cited a standard methodology used by the UK government, based on a European Union study with data collected in 2012 for translating the LNG volume into emissions, rather than any kind of detailed analysis specific to the actual cargo.[126] This illustrates the very limited transparency surrounding these cargos.

Offsets related to these cargos introduce another level of complexity. Carbon credits are a major subject in themselves, discussion of which is beyond the scope of this study.[127] There are a range of projects (including efficiency, forestry, renewable energy, emissions capture) and a range of registries for the credits. Carbon-neutral LNG cargos have used credits from the voluntary carbon market which is rapidly increasing in size and popularity. More than half of the cargos have used the Verified Carbon Standard (Verra), others used include the Climate Action Reserve, American Carbon Registry, Gold Standard, and California Climate Action.[128]

Estimated costs of credits vary. Blanton and Mosis used a forestry-based carbon credit range of $4–7/metric tonne of CO_2e (based on 2019 data) which, assuming a standard 70,000 tonne cargo of LNG, would result in an additional payment of up to $1.75m/cargo or $0.4–0.55/mmbtu.[129] These costs would have looked high in 2020 when LNG prices were in low single digits, but much less at the price levels of 2021. In 2021, Platts launched a carbon-neutral LNG price assessment of Corsia-eligible credits in the voluntary carbon market; estimates for third quarter 2021 costs were $0.46–0.51/mmbtu.[130]

So far as can be judged without the benefit of publicly available documentation, carbon-neutral cargos appear to attribute a standard volume of emissions to a cargo based on a standard methodology which is then matched to an offset for that volume. This falls significantly short of a requirement for accurate MRV of emissions from individual cargos, without which it is impossible to know what size of offset is required.[131] Without empirical measurement and verification of emissions from these cargos, and much more transparency about the process, the credibility of carbon-neutral transactions is open to serious question, and even the term is a misnomer. The following sections provide examples of alternative MRV methodologies and supporting data.

The Statement of Greenhouse Gas Emissions (SGE) Methodology[132]

In 2020, Pavilion Energy issued a tender for up to 2 mt of LNG with a defined GHG content, with supply to commence in 2023. Three contracts have been signed: a 10-year contract for up to 1.8 mt/year of LNG with Qatar Petroleum Trading; a six-year contract for 0.5 mt/year with Chevron, and a 10-year contract for 0.8mt/year with BP; with delivery to Singapore. The first two contracts start in 2023 and the third in 2024.[133] These contracts are different from the carbon-neutral cargoes discussed above. They are long-term sale and purchase agreements which do not require either seller or buyer to offset all the emissions – in other words, they are not (necessarily) GHG neutral.

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[125] In some cases it is possible to track the transaction in the database of an offset registry to obtain some of the detail of the parties.
[126] Shell (2021a) and (2021b) used the (formerly DEFRA, now) UK Department for Business, Energy and Industrial Strategy (BEIS) conversion rates to calculate the LNG emissions needed to be offset for Scope 1, 2, and 3. For details of this methodology see Appendix 6. The RWE–Posco trade used the Wood Mackenzie LNG emissions tool.
[127] For an extensive discussion see Bose et al. (2021) and Blanton and Mosis (2021), pp. 11–15.
[128] Poten and Partners (2021).
[129] Blanton and Mosis (2021), p.14. But this is based on the UK Government methodology in Appendix 6. Shiryaevskaya and Krukowska (2020) have a higher estimate of $2.4m/cargo which would add around $0.70–0.80/mmbtu based on a standard cargo containing roughly 304,000 tonnes of CO_2. Platts also publishes prices for tradeable methane performance certificates https://www.spglobal.com/platts/en/products-services/energy-transition/methane-performance-certificates#
[130] Hodgson (2021).
[131] Ibid, for details of offset trading see Bose et al. (2021).
[132] SGE (2021). The document runs to more than 100 pages and only a very brief summary is given here.
[133] Pavilion Energy (2020), Pavilion Energy (2021a), BP (2021c).

The parties have created an MRV methodology to 'create a consistent, verified SGE for each delivered LNG cargo', from production to the delivery point at the import terminal.[134] The methodology covers all operational emissions associated with these life cycle stages, quantified and reported per cargo both as total GHG emissions in CO_2 equivalent and methane intensity per energy content delivered expressed in tons of methane per mmbtu. At a minimum, emissions of carbon dioxide, methane, and nitrous oxide must be included. The methodology includes: reporting principles, boundaries (segments), quantification and allocation methods, reporting and assurance. Each Statement of Emissions requires a report containing: cargo details, GHG data (intensity and emissions breakdown) and verification details. Reporters are required to use the highest-quality data which (for operated assets) is expected to be primary data. For SGEs to achieve a 'reasonable' level of assurance, a third-party verifier must assure that emissions have been calculated per the methodology with no material errors or omissions.[135] Continuous improvements in data quality and transparency are expected over time.

The GIIGNL MRV and GHG-Neutral LNG Framework

GIIGNL is an organisation representing companies active in the import and regasification terminalling of LNG. It has 86 members representing the LNG import industry from around the world in the Americas, Asia and Europe. In November 2021, it launched a framework from MRV of emissions from LNG and for offsets of emissions.

This framework has been designed to:[136]

- Provide a common source of best practice principles in the monitoring, reporting, reduction, offsetting, and verification of GHG emissions associated with a delivered cargo of LNG.
- Promote the commitment to, and disclosure of, verified emissions on consistent GHG accounting criteria and definitions, facilitating the calculation of an LNG cargo GHG footprint that genuinely reflects its climate impact.
- Promote a consistent approach to declarations related to emission reduction actions and carbon offsets that are associated with an LNG cargo.
- Position emission reduction action as the primary focus of a claim of 'neutrality', with the use of offsets to compensate for residual emissions that cannot be reduced.
- Promote full accounting for methane emissions as well as carbon dioxide and other applicable GHGs.

The Framework differs from that of SGE in that it includes the full life cycle of emissions from production to end use. It also retains the term 'neutral' – but GHG neutral rather than carbon neutral – and therefore encompasses offsets rather than only MRV of emissions.

> 'Reporters will use the Framework to quantify the GHG emissions associated with a delivered cargo in a "GHG footprint" statement. They then have the option to make a claim of "GHG Offset", "GHG Offset with Reduction Plan" or "GHG Neutral" Cargo.'[137]

The Framework includes a Cargo Statement which requires companies to provide detail of: the different segments of the life cycle, emissions from those segments, the standards applied, the offsets used, an emissions reduction plan and (if claimed) a GHG neutrality declaration.[138] The Framework has the same levels of assurance as SGE and the verifier is required to issue an opinion set out in ISO 14064-3:2019.[139]

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[134] Wording in this paragraph is taken directly or summarized from SGE (2021), pp. 4–6. It is not clear whether the contract with BP includes the same terms (the companies named on the front page of the document do not include BP).
[135] 'Reasonable' is the higher level of assurance, the other level is 'limited', defined under ISO14064:2019. SGE (2021), pp.59–60.
[136] GIIGNL (2021b). The Framework comprises a substantial set of documents which are very briefly summarised here. This paragraph is quoted verbatim from p.1 of the Executive Summary.
[137] Ibid, p.2.
[138] Ibid, Annex E.
[139] Ibid, pp.38–9.

Emissions from Cheniere's LNG exports

The problems of tracing the molecules of a US LNG cargo from a specific production site to a specific liquefaction terminal, and from there on a specific ship to a specific destination have already been discussed (in Section 4). A detailed study of the lifecycle emissions of CO_2, methane, and nitrous oxide from Cheniere's cargos exported from its Sabine Pass terminal in 2018 has been published in an academic journal.[140]

Emissions from the Cheniere study are 1.18tCO_2e/tLNG and 1.64tCO_2e/tLNG for emissions from the wellhead to delivery to the Chinese border (in other words, before regasification) for a 100-year and a 20-year GWP respectively.[141] The Cheniere results are significantly below similar estimates for US deliveries to China by Gan et al. (2020) – 1.67 tCO_2e/tLNG and 2.89 tCO_2e/tLNG; and Roman-White et al. (2019) – 1.83tCO_2e/tLNG and 2.49 tCO_2e/tLNG, for 100-year and 20-year GWP time horizons respectively.[142] Emission estimates from the supply chain from wellhead to liquefaction are divided into the following stages.[143]

The upstream supply chain (production through transmission) to the LNG facility: this is modelled as a 58 per cent/42 per cent split between Cheniere's known suppliers and gas trading entities, based on purchasing records for 2018.[144] For known suppliers, estimates were modelled using basin-level data available from their Subpart W filings (and data from the operators on their non-Subpart W assets) which in some cases included data from individual well-pads.[145] Traders treat information about their suppliers as confidential, but more granularity about these supplies can be obtained from recorded delivery points of receipt on the transmission network which give a good (but not an exact) indication of the basin from which the gas originated. Where the gas is associated with oil, the study employed the ISO protocol and co-allocation via the ONE Future and NGSI protocols which were also used to calculate emissions from upstream gathering and boosting.[146] With respect to gas processing, emissions are allocated between natural gas and NGLs. The study models the percentage of gas which passes through the lifecycle stages of the supply chain from production to the liquefaction plant, contrasting Cheniere's known suppliers with the US average, with the biggest differences being the length of transmission lines and the number of compressor stations.[147]

The liquefaction facility: to calculate the intensity of the Sabine Pass liquefaction facility, the study uses Cheniere's submissions to EPA GHGRP Subpart W (emissions from fugitives, venting, and flaring) and Subpart C (combustion emissions) data and provides parameters for each of the gases.[148]

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[140] Roman-White et al. (2021a) and Roman-White et al. (2021b), hereafter referred to as 'the Cheniere study'. Two Cheniere employees co-authored the study with four academics and three consultants; it was funded by Cheniere.

[141] The values used for the carbon dioxide equivalent over a 100-year and a 20-year horizon are 36 and 87 for methane, and 298 and 268 for nitrous oxide, respectively.

[142] Gan et al. (2020); Roman-White et al. (2021a) Figure 2. The data are for deliveries to China and do not include emissions from regasification or from the import market.

[143] As noted above, the Cheniere study is a full lifecycle model from production to end-use of which only a few details of some of the nine stages are described here. Readers are advised to consult Roman-White et al. (2021a) and (2021b) for more details.

[144] Ibid, Table S7 lists the parameters for CO_2, methane, and nitrogen oxide for 40 unit processes. Some unit processes use other parameters (also provided in Table S7) related to activity data/efficiencies.

[145] Roman-White et al. (2021b), p.S7. Subpart W refers to a mandatory reporting requirement of fugitive emissions, those from flaring and venting, and other combustion emissions (for example, from compressors) to the US Environmental Protection Agency's Greenhouse Gas Reporting Programme (GHGRP). Cheniere has a research partnership with five of their suppliers to develop MRV of GHG emissions for production from four basins. Cheniere (2021c).

[146] ONE Future (2020) and NGSI (2021). Roman White et al. (2021b), p.S27.

[147] Gan et al. (2020); Roman-White et al. (2021b), Table S5, p.S24. This is from a supply chain perspective, but different parameter sets are included in Table S7, pp. S32–S40.

[148] Ibid, Table S8, p.S43. Cheniere's submissions for its Corpus Christi LNG terminal can be found at: https://ghgdata.epa.gov/ghgp/service/facilityDetail/2020?id=1013179&ds=E&et=&popup=true. These include the Acid Gas Removal Unit (AGRU) which is also accounted in the model (not currently a reporting requirement under GHGRP). Ibid, Table SI3, p.18.

Shipping: estimating emissions from ocean transportation of LNG to the destination market requires another set of significant complexities to be taken into account. Emission estimates from shipping vary more than for any other part of the supply chain, as they depend on the distance travelled and the characteristics of the ship. In the Cheniere study, the scale of emissions from shipping ranged from 0.05tCO_2/t LNG delivered, or a 6 per cent contribution to the total lifecycle emissions for a cargo delivered to Jamaica, to 0.31tCO_2/t LNG (a 27 per cent contribution) for a cargo delivered to Taiwan.[149] Considerations which need to be taken into account in making this calculation are: emissions from the round-trip of the ship (including the ballast voyage as well as the voyage to deliver the LNG), methane slip for the propulsion system of the ship, and the usage of boil-off gas.[150] In addition, different fuel and engine combinations result in very different emission levels.[151]

The Cheniere study has provided a detailed framework for tracing emissions through the export supply chain which, with adjustments, will be applicable more widely for US LNG exporters to provide credible estimates of their emissions. Because of these complexities, calculations of GHG emissions for LNG (and pipeline gas) exports will require a range of assumptions in the supply chain where tracing the export molecule back to the wellhead cannot be achieved with complete accuracy. The study can undoubtedly be refined and improved upon, but for this author it provides a credible benchmark against which the methodology and data of other LNG (and pipeline gas) exporters can be compared.

The principal shortcoming when measured against the SGE and GIIGNL frameworks is that it does not provide for independent verification of measurement and data.[152] Within a US context of a company buying 50–60 bcm/year of gas from around 100 companies which may each be producing gas from hundreds (and possibly thousands) of wells, verification of emissions from each well would be an infeasibly large (and probably impossible) task. Added to these complexities are the tasks of monitoring the path of the gas through multiple pipelines, processing plants and storages. Cheniere relies on the EPA's Report Verification under the Greenhouse Gas Reporting Programme and the Certificate of Truth Accuracy and Completeness to ensure that the Subpart W and Subpart C documents submitted by its suppliers are correct.[153] The framework will 'go live' when Cheniere's commitment to provide buyers with emission tags for every cargo starts in 2022.[154]

The SGE, GIIGNL, and Cheniere initiatives are welcome steps forward in terms of credibility of MRV of emissions from global LNG trade. They represent starting points for MRV of GHG emissions from LNG trade which need to be further refined and replicated in relation to pipeline gas trade. A question which GIIGNL and the Cheniere study raise, at least for this author, is whether LNG sellers are in a position to make a detailed and credible MRV assessment of emissions from the buyer's market. In complex import markets[155], buyers and national regulators, are the only entities which can make such an assessment given the required detail of emissions from transmission, distribution, and the customer base.

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[149] Roman-White et al. (2021a), Figure 3. There can be significant variability between suppliers within a single basin and between basins, the data here are weighted averages.

[150] 'Methane slip' is fugitive emission of unburnt fuel from the ship's engines. A percentage of the LNG 'boils off' (in other words, it evaporates) during the voyage. In modern LNG ships this gas is collected and used as fuel for the ship, minimizing emissions. There is a detailed account of these factors in Roman-White et al. (2021b), pp. S44–S58.

[151] Balcombe et al. (2021) examine these issues in detail.

[152] SGE (2021), pp. 61–63; GIIGNL (2021b), pp.38–9.

[153] EPA (2020). The verifier/representative of the company is required to sign the following statement: 'I certify that the statements and information are to the best of my knowledge and belief true, accurate, and complete. I am aware that there are significant penalties for submitting false statements and information or omitting required statements and information, including the possibility of fine or imprisonment.'

[154] Cheniere (2021a).

[155] Markets where gas is delivered to large numbers of different power, industry and residential/commercial consumers through complex transmission and distribution networks.

6. The IMEO and OGMP Version 2.0: consolidated reporting, confidentiality, and verification

The International Methane Emissions Observatory (IMEO)

The IMEO Methane Observatory was included in the EU Methane Strategy and launched with the Oil and Gas Methane Partnership Version 2.0 (henceforth OGMP 2) in November 2020. Its core functions are to act as a global data hub for methane in three respects:[156]

- Transparency: to provide accurate, unbiased, and up-to-date information on methane emissions attributable to fossil fuel operations at different levels of aggregation;
- Science: to close the knowledge gap in the location and magnitude of methane emissions along fossil fuel value chains through peer-reviewed studies and the reconciliation among observational data;
- Implementation: to raise awareness and increase the capacity of governments to pursue science-based policy options to manage methane emissions from the fossil fuel sector.

The Oil and Gas Methane Partnership Group (OGMP) of the UN Climate and Clean Air Coalition (CCAC) is regarded as the 'gold standard' of methane emissions reporting.[157] It has five levels of reporting, with companies needing to achieve levels 4 and 5 to be regarded as having achieved OGMP's own 'Gold Standard':

- Level 4 – emissions reported by detailed source type and using specific emissions factors and activity factors.
- Level 5 – emissions reported similarly to Level 4 but with the addition of site-level measurements (measurements that characterize site-level emissions distribution for a statistically representative population).

The IMEO's first set of initiatives will focus on the oil and gas sector and the implementation of the Oil and Gas Methane Partnership (OGMP 2) framework. In 2022–2023 the Observatory plans to launch a second version of its integrated data platform, and in 2025 and 2026 the founding member companies are committed to achieving the Gold Standard for operated and non-operated assets (respectively) based on data for the previous years.[158] In addition, IMEO:

> 'will explore the possibility of compiling and publishing a Methane Supply Index (MSI) reflecting the methane emissions embedded in oil and gas in different jurisdictions.'[159]

As noted above (Section 2) the MSI will be created using data from the transparency database proposal in the EU methane regulation, which will enable buyers of imported gas and their governments and end-users to compare emissions of methane from different sources.

Two immediate problems arise from this geographically ambitious initiative: the first is that governments and companies of important gas importing and exporting countries have not yet signed the Global Methane Pledge.[160] In addition, IMEO membership and adoption of the OGMP2 framework remains

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[156] United Nations Environment Programme (2021).
[157] OGMP (2020).
[158] Ibid, p.13.
[159] Ibid, p.4, and see Section 2 above where this is rather more definitely stated in the EU Methane Regulation. A second set of IMEO initiatives under development will address methane emissions from coal mining.
[160] Signatories of the Pledge can be found at https://www.globalmethanepledge.org/ members of OGMP2 be found at https://www.ogmpartnership.com/partners As noted above (note 10) notable important gas importing and exporting countries absent from the list of signatories in November 2021 were: China, India, Russia, Qatar, Australia, Algeria, Egypt, Azerbaijan, and Turkmenistan.

heavily concentrated in Europe with 74 companies representing one third of the world's (operated and non-operated) oil and gas production.[161] The second is that, as we have shown in Sections 3 and 4, emissions from a methane supply index based solely on (oil and) gas production will give very different results compared with emissions based on export supply chains.

Ultimately the success of IMEO will depend on measures proposed in the EU Methane Strategy which were to:[162]

- create a coalition of major LNG buyers to support an ambitious international monitoring, reporting and verification standard this would have a significant impact on LNG trade;
- lead a diplomatic outreach campaign to fossil fuel producer countries and companies and encourage them to become more active in the Oil and Gas Methane Partnership (OGMP)…[and] explore the possibility of providing partner countries with technical assistance in gas and oil production so these countries can improve their methane regulatory frameworks and their capacity in monitoring, reporting and verification.

A number of other industry groups have made individual and collective commitments to reduce emissions of methane to specified levels within defined time periods and have appointed their own certification organizations to report emissions.[163] There is a focus on different parts of the supply chain, with some only (or mainly) concerned with upstream emissions and others on a much wider spectrum of activities including CCUS.[164] In contrast to IMEO and OGMP, membership of some of these groups is North America-focussed.

Within the European Union, industry bodies have collaborated to develop a value chain approach to methane emissions. Gas Infrastructure Europe (GIE) and Marcogaz's Methane Emissions Action Plan cover the domestic transportation and distribution segments of the natural gas supply chain (including LNG regasification terminals) within the EU involving all the main industry associations, and the main requirements of data collection and reporting, as well as harmonized methodologies and quantification of data.[165]

The problem of confidentiality

These initiatives feature absolute or intensity targets for methane (and some for GHG) emissions, for 2025 and 2030 for individual companies and groups. They also envisage 'consolidated reporting', namely emissions covering all of the operations of a single company or group, rather than asset-level reporting. Confidentiality requirements are relatively stringent, for example Principles 4 and 5 of the OGMP 2 reporting framework:[166]

- 'Reporting is done confidentially by "reporting unit" with public disclosure on a consolidated corporate basis …
- If companies are not permitted to share data from any of their operated or non-operated venture assets, they will provide evidence of why this is the case'.

The OGMP 2 framework for both operated and non-operated ventures envisages:

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[161] UNEP (2021). In September 2021, of the companies in Table 2, only Equinor and Qatar Energy were OGMP2 members, and no US companies appear in the list.
[162] European Commission (2020), pp.16-17. A statement on energy diplomacy focusing only on the Global Methane Pledge is included in the Regulation, European Commission (2021a), Recital 54, p.22
[163] Other groups include: Methane Guiding Principles (2020), Oil and Gas Climate Initiative (OGCI 2020), Collaboratory to Advance Methane Science (CAMS), Global Methane Initiative (GMI) and ONE Future (2020).
For example, OGCI is pledging to reduce the collective methane intensity of its member companies from a 2017 baseline of 0.32%, to below 0.25% by 2025, with the ambition to achieve 0.20%. OGCI (2020). GIE and Marcogaz (2019) sets out guidelines for methane emissions target setting. A complete set of documents can be found on the website, https://www.marcogaz.org/knowledge-hub/#publications
[164] OGCI (2020) has targets for both methane and CO_2 and is involved in downstream decarbonization and CCUS.
[165] The bodies are principally: Gas Infrastructure Europe (GIE), Marcogaz, and IOGP but also include the upstream voluntary associations such as OGCI, Methane Guiding Principles, and others noted above.
[166] OGMP (2020), section 4.1.

'a reasonable and demonstrable effort for reporting emissions while recognizing that there are barriers to securing full or partial disclosure of methane emissions from joint venture partners, including legal compliance.'[167]

It also includes the following statements in relation to confidentiality of joint venture assets:[168]

- 'Where confidentiality provisions of joint venture agreements do not allow for the disclosure of this data …
- Where data is not available or joint venture or other applicable agreements do not currently allow for sharing …
- All information and data supplied by member companies to UNEP … shall be kept confidential and may not [be] disclosed to third parties …
- UNEP may disclose information consolidated … provided that member companies will have reasonable opportunity to review and raise comments prior to the publication …'

Other frameworks also allow information to remain confidential or are unclear on whether disclosure will be public.[169] These provisions prevent the transparency of emissions from individual assets of a particular supply chain. OGMP 2 member companies disclose this data to IMEO, but there are limitations on making them more widely available. The reason given is that it is not the emissions per se that are the problem, but production from the asset – which can be calculated from emissions – that companies regard as commercially confidential. For this author, such arguments have little credibility. It is possible to argue that financial aspects of commercial transactions related to emissions (such as offsets) should remain confidential (but even this can be questioned).

Companies will need to be required by governments or regulators to disclose their emissions, or to permit IMEO to do so. 'Confidentiality' can be viewed as a way of hiding emissions which can (and in many cases will) be interpreted by industry outsiders as much higher than those reported. The international gas community needs to recognize that, among certain groups, there is considerable scepticism about the validity of any emissions data provided by the industry. Any aspiration to environmental credibility will therefore require transparency without conditions. Continued insistence on confidentiality of data on emissions risks being interpreted as 'greenwash'.

Verification, certification and assurance

An important role in relation to data credibility will be played by verifiers or certifiers of methane emissions based on common standards. Chapter 2 of the proposed EU Regulation requires member states to designate 'competent authorities'[170] which will specify the preparation of reports based on inspections they are required to carry out, which will then be examined by 'accredited verifiers'.[171] Verifiers need to be 'third-party organizations' with no link to the owners of the gas, the owners or operators of the assets, or the competent authorities. This may mean different verifiers for different classes of asset along the supply chain. Article 5(3) states that:

`The competent authorities shall cooperate with each other and with the Commission and as necessary with the authorities of third countries, in order to ensure compliance with this Regulation. The Commission may set up a network of competent authorities to foster cooperation with the necessary arrangements for exchanging information and best practices and all of consultations.'

[167] Ibid, section 4.21. There are confidentiality provisions in GIIGNL (2021b), p. 36 and 41.
[168] Ibid, section 5.
[169] The SGE framework (p.15) requires disclosure in relation to completeness and transparency but it is not clear whether this means publication. The GIIGNL framework (p.36) allows data, measurement and monitoring to remain confidential to external parties. Article 13(10} of the proposed EU Regulation states: `Where information is kept confidential…operators shall indicate in the report the type of information that has been withheld and the reason thereof.'
[170] The term `competent authorities' is EU-speak for regulators chosen by member states.
[171] European Commission (2021a), Articles 4–10.

The SGE and GIIGNL frameworks set out the necessary content of, and qualifications for, verification. SGE has a chapter on assurance which includes sections on the content of the verification statement and documentation, and verifier selection and competence.[172] GIIGNL has verification and assurance in the `conformity' section of the Cargo Statement, as well as setting out the required content of the verification report.[173] Verification by accountancy organizations with limited technical expertise or sampling ability is not likely to be considered acceptable.[174] As noted above, there are two levels of assurance under ISO standards: 'reasonable' – which is the highest level and provides good confidence that the LNG cargo footprint is reliable; and 'limited' – which provides confirmation that the recommended approach has been followed but with a lower coverage of data from individual assets and companies.

Key issues for verification and certification are: frequency of observations, reconciliation of bottom-up and top-down measurements, and uncertainty levels of results. Each of these requires specific examination, together with the details of the equipment which is being used to measure emissions. In 20211, third party certification started on a large scale in the US. Different organizations use different criteria for emission levels. MIQ has five grades, A–F, with intensities of 0.05–2.00 per cent and, by November 2021, had certified 100 bcm of gas production in the United States and is extending certification through the supply chain for LNG exports.[175] It is expected that 2022 will see the start of certified cargos of US LNG, but it is unclear what levels of measurement have been carried out, which segments of the export supply chain they cover, and how the resulting data have been verified. In October 2021, Platts launched pricing assessments for methane performance certificates – representing the production of a specific volumes of natural gas at an intensity of 0.1% or less.[176] The segment which such products are measuring, the methodologies used for these very complex assessments, and the level of uncertainty associated with the results, may be as important as the resulting 'number'. All frameworks anticipate – and most require – continuous improvements in MRV as technologies and practices are established and evolve.

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[172] SGE (2021), Chapter 5.
[173] GIIGNL (2021b), p.39.
[174] SGE (2021), p.57 and GIIGNL (2021b), p.38 both state that verifiers should meet the qualification criteria set out in ISO14065:2020.
[175] 'The methane mission': https://miq.org/ has full details of the MIQ framework.
[176] Hallahan and Burke (2022), https://www.spglobal.com/platts/en/products-services/energy-transition/methane-performance-certificates#

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7. Appendices

Appendix 1: The Global Warming Potential (GWP) of methane relative to CO_2 over different time horizons

IPCC AR5 used a 100-year horizon and noted this was the

' ... most widely used by governments but we are mindful that other time horizons and other global warming metrics also merit attention'.[177]

With the adoption of COP21 and Net Zero targets for 2050, many commentators have suggested that the 20-year horizon is a much more appropriate value for GWP than the 100-year horizon agreed by the IPCC governments and widely used by the fossil fuel community. Each organization and publication adopts a different time horizon and GWP value for methane around the values stated in Section 1. For our purposes, the most important issue is the transparency of the value for methane if this is translated into GWP CO_2 equivalent (CO_2e) data. We also note that some experts believe that it is not possible to credibly express the two gases in equivalent terms, which would mean that GWP and CO_2e data is at best misleading and at worst worthless.[178]

The conclusion of Balcombe et al. (2018) deserves to be taken seriously by all institutions and companies which generally give a single figure for methane in a footnote to their data and analysis:

> ' … the use of climate metrics in GHG estimation must be carried out with great care and the standard usage of a single global warming potential is not acceptable as it may hide key trade-offs between long and short term climate impacts. It is vital to test any GHG estimates with high and low equivalency values to ensure we are not simply replacing long-term climate forcing with short-term, or vice versa'

To promote transparency and credibility, the gas community should report emissions in tonnes of methane and CO_2 equivalent, making clear its own conversion and time horizon but allowing others to use alternative metrics.

[177] IPCC (2014), p.125. The other major metric is global temperature potential (GTP) which, it is argued, is more appropriate than GWP because the main concern is the impact on global temperatures rather than concentrations of gases in the atmosphere.
[178] Shine (2009), Kleinberg (2020) and (2021 forthcoming).

Appendix 2. Methane emissions – natural and anthropogenic sources and measurement methods[179]

Methane is emitted from natural sources (principally wetlands and freshwaters) and anthropogenic sources, of which the largest are agriculture (ruminants from livestock), landfill and waste, and fossil fuels (oil, gas, and coal).[180] Table 10 shows data for 2017 (the most recent available) measured by top-down and bottom-up methods. In each case, ranges are given, some of which are very wide, indicating significant uncertainty of the estimates.

Table 10: Global Methane Emissions by Source (TgCH4/year)

	2008–2017		2017	
	Bottom-up	Top-down	Bottom-up	Top-down
Natural Sources	368 (242–485)	218 (183–248)	367 (243–489)	232 (194–267)
Anthropogenic Sources	366 (349–393)	359 (336–376)	380 (359–407)	364 (340–381)
of which:				
Agriculture and waste	206 (191–233)	217 (207–240)	213 (198–232)	227 (205–246)
Fossil fuels total	128 (113–154)	111 (81–131)	135 (121–164)	108 (91–121)
of which:				
Oil and gas	80 (68–92)	n/a	84 (72–97)	n/a
Coal	42 (29–61)	n/a	44 (31–63)	n/a

Source : Saunois et al. (2020), Table 3.

Table 11 shows the same data expressed as percentages, from which it is immediately clear that top-down measurements attribute an additional 12 per cent to anthropogenic sources for 2008-17 (10% for 2017 alone) compared with bottom-up measurement. Of the main anthropogenic sources, 56–62 per cent are from agricultural sources and 30–35 per cent from fossil fuels (bottom-up measurement tends to show increased shares of fossil fuels).[181] The shares of fossil fuels break down roughly two-thirds oil and gas and one-third coal, no top-down estimates are available for the different fossil fuels. However, increasing use of satellite data with increasing geographical accuracy has begun to transform information about oil and gas emissions on a real-time basis, particularly for countries where no information about emissions is available or where data and methodologies are insufficiently transparent.

[179] More detail on the issues summarized in this section can be found in Stern (2020), pp.3–17.
[180] UN/CCAC (2021), Table 2.1, p.27. Natural sources estimates were 232mt (range 194–267mt). Anthropogenic source estimates 364mt (range 340–381mt) of which oil and gas 84mt (72–98mt) and coal 44mt (31–63mt).
[181] The remaining anthropogenic shares are from biomass.

Table 11: Proportion of Methane Emissions Attributed to Natural and Anthropogenic, and Different Anthropogenic Sources

	2008–2017		2017	
	Bottom-up	Top-down	Bottom-up	Top-down
Natural Sources	50%	38%	49%	39%
Anthropogenic Sources	50%	62%	51%	61%
of which:				
Agriculture and waste	56%	60%	56%	62%
Fossil fuels total	35%	31%	35%	30%
of which:				
Oil and gas	63%	n/a	62%	n/a
Coal	33%	n/a	33%	n/a

Source: Saunois et al. (2020), Table 3.

Appendix 3: ANNEX VIII of the proposed EU Methane Regulation - Information to be Provided by Importers[182]

For the purposes of this Annex, 'exporter' means the contractual counterparty in each supply contract entered into by the importer for the delivery of fossil energy into the Union.

Pursuant to Article 27, importers must provide the following information:

I. name and address of exporter and, if different from exporter, name and address of producer;

II. country and regions corresponding to the Union nomenclature of territorial units for statistics (NUTS) level 1 where the energy was produced and countries and corresponding to the Union nomenclature of territorial units for statistics (NUTS) level 1 through which the energy was transported until it was placed on the Union market;

III. as regards oil and fossil gas, whether the exporter is undertaking measurement and reporting of its methane emissions, either independently or as part of commitments to report national GHG inventories in line with United Nations Framework Convention on Climate Change (UNFCCC) requirements, and whether it is in compliance with UNFCCC reporting requirements or in compliance with Oil and Gas Methane Partnership 2.0 standards. This must be accompanied by a copy of the latest report on methane emissions, including, where available, the information referred to in Article 12(6). The method of quantification (such as UNFCCC tiers or OGMP levels) employed in the reporting must be specified for each type of emissions;

IV. as regards oil and gas, whether the exporter applies regulatory or voluntary measures to control its methane emissions, including measures such as leak detection and repair surveys or measures to control and restrict venting and flaring of methane. This must be accompanied by a description of such measures, including, where available, reports from leak detection and repair surveys and from venting and flaring events with respect to the last available calendar year;

V. as regards coal, whether the exporter is undertaking measurement and reporting of its methane emissions, either independently or as part of commitments to report national GHG inventories in line with United Nations Framework Convention on Climate Change (UNFCCC) requirements, and whether it is in compliance with UNFCCC reporting requirements or in compliance with an international or European standard for monitoring, reporting and verification of methane emissions. This must be accompanied by a copy of the latest report on methane emissions, including, where available the information referred to in Article 20(6). The method of quantification (such as UNFCCC tiers or OGMP levels) employed in the reporting must be specified for each type of emissions;

VI. as regards coal, whether the exporter applies regulatory or voluntary measures to control its methane emissions, including measures to control and restrict venting and flaring of methane. This must be accompanied by a description of such measures, including, where available, reports from venting and flaring events with respect to the last available calendar year;

VII. name of the entity that performed independent verification of the reports referred to in points (iii) and (v), if any.

[182] European Commission (2021c).

Appendix 4: Methane emissions data from UNFCCC submissions for the United States, the Russian Federation, and Norway for the period 2010–2019

As Table 12 shows methane emissions from submissions by the United States, the Russian Federation, and Norway to the UNFCCC for the period 2010–2019 for the natural gas industry, and includes some data for oil.[183] As noted in the main text, the merit of this data is the long time series allowing comparisons over time as to whether emissions are increasing or decreasing. But the data also have many problems of interpretation of which the main ones are:

- Lack of standardized reporting; the table shows that detail provided by countries is very different. In some categories the submissions cite 'included elsewhere' (IE in the source) or not collected (NO in the source). With only one exception, Table 12 only includes categories where actual values are given.
- Lack of methodological explanation of how the data are compiled and in particular whether measurement and reporting standards have changed during the period;
- Lack of differentiation – or complete absence of data – in relation to whether these 'fugitive emissions' are intentional (such as venting or incomplete flaring) or unintentional leakages from pipelines.

In the US data, oil and gas dominate the fugitive emissions from the energy sector, more so than in Russia. The main sources are reported in 'oil production', 'gas production', and 'gas transmission and storage'. Emissions from flaring and venting are not reported at all and are included elsewhere (but not separately itemized).

In the Russian data, most of the emissions are allocated to oil production, or to gas transmission and storage, not to gas production. All reported venting is from oil activities/assets, so too is almost all flaring. Very limited emissions are attributed to gas production, which may reflect the way the authorities have chosen to report the data.

In the data for Norway, all upstream oil and gas emissions are reported under flaring or venting, not under exploration and production.

[183] The UNFCCC data also includes emissions from all energy industries including from solid fuels (coal). Only emissions directly relevant to natural gas are shown in Table 3.1 and discussed here. UNFCCC (2021).

Table 12: UNFCCC Methane Emissions Submissions from the US, Russia and Norway, 2010-19 (thousand tons of methane)

				2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
UNITED STATES													
Natural Gas													
	Exploration		*1.B.2.b.i*	229	227	97	114	37	42	28	49	33	21
	Production		*1.B.2.b.ii*	3,644	3,662	3,688	3,697	3,586	3,572	3,466	3,574	3,631	3,748
	Processing		*1.B.2.b.iii*	402	400	400	429	440	440	448	460	483	497
	Transmission and Storage		*1.B.2.b.iv*	1,211	1,171	1,167	1,238	1,293	1,366	1,379	1,298	1,390	1,478
	Distribution		*1.B.2.b.v*	645	595	591	586	580	574	573	569	565	560
	Other		*1.B.2.b.vi*	54	55	56	57	58	59	60	58	59	55
	Total natural gas		**1.B.2.b**	6,185	6,110	6,000	6,121	5,994	6,052	5,953	6,007	6,161	6,359
Venting and Flaring - all data `included elsewhere'													
Total Oil and Gas (fugitive)			**1 B 2**	**8,011**	**8,007**	**7,899**	**8,120**	**8,003**	**7,947**	**7,758**	**7,811**	**7,884**	**8,131**
RUSSIAN FEDERATION													
Natural Gas													
	Production		*1.B.2.b.ii*	126	130	126	128	121	118	119	129	136	137
	Transmission and Storage		*1.B.2.b.iv*	2,700	2,654	2,452	2,301	2,064	1,864	1,799	1,279	1,320	1,284
	Distribution		*1.B.2.b.v*	518	536	529	515	517	497	495	518	563	569
	Total natural gas		**1.B.2.b**	**3,344**	**3,321**	**3,106**	**2,944**	**2,702**	**2,480**	**2,412**	**1,926**	**2,018**	**1,991**
Venting and Flaring	*Venting*												
		Oil	1.B.2.c.i.1	427	433	438	441	445	453	464	462	470	475
		Gas	1.B.2.c.i.2	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*
	Total venting		*1 B 2 c i*	427	433	438	441	445	453	464	462	470	475
	Flaring												
		Oil	1.B.2.c.ii.1	183	199	205	187	142	118	132	156	188	244
		Gas	1.B.2.c.ii.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Total flaring		*1 B 2 c ii*	184	199	205	187	142	118	132	156	188	244
	Total venting and flaring		**1.B.2.c**	610	632	643	628	587	571	595	619	659	719
Total Oil and Gas (fugitive)			**1 B 2**	**5,145**	**5,159**	**4,971**	**4,801**	**4,529**	**4,312**	**4,299**	**3,833**	**3,987**	**4,034**
NORWAY													
Natural Gas													
	Distribution		*1.B.2.b.v*	0.81	0.93	1.03	1.02	1.01	1.04	1.01	1.10	1.03	1.03
	Other		*1.B.2.b.vi*	2.19	2.24	1.81	2.08	2.08	2.06	1.95	2.10	2.08	1.93
	Total natural gas		**1.B.2.b**	3.00	3.17	2.84	3.10	3.09	3.11	2.96	3.20	3.11	2.95
Venting and Flaring													
	Venting (oil and gas)		*1 B 2 c i*	8.10	7.70	7.94	7.55	7.66	8.07	8.17	8.36	8.03	6.87
	Flaring												
		Oil	1.B.2.c.ii.1	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Gas	1.B.2.c.ii.2	1.81	1.97	2.01	2.07	1.95	2.02	1.82	1.78	1.78	1.81
	Total flaring		*1 B 2 c ii*	1.82	1.97	2.02	2.07	1.95	2.02	1.82	1.78	1.78	1.81
	Total venting and flaring		**1.B.2.c**	9.93	9.67	9.96	9.63	9.61	10.08	9.99	10.14	9.81	8.68
	Total Oil and Gas (fugitive)		**1.B.2**	**25.94**	**24.79**	**24.07**	**23.26**	**22.42**	**22.80**	**20.70**	**19.15**	**19.29**	**17.91**

Source: UNFCCC (2021).

Appendix 5: Gazprom and Novatek GHG Emissions

Table 13: PJSC Gazprom Emissions by type of activity mt CO_2e

	2016	2017	2018	2019	2020
Production	11.6	13.07	14.39	15.01	14.27
Transmission	82.2	92.28	97.52	93.65	77.61
Underground Gas Storage	1.2	1.34	1.44	1.33	1.3
Processing	5.41	5.46	5.71	5.99	6.83
Other	0.83	1.02	1.03	1.11	1.13
TOTAL	**101.24**	**113.17**	**120.09**	**117.09**	**101.14**
Methane Emissions CO2e					
	2020	% of total in each activity			
Production	1.19	0.02			
Transmission	23.82	0.24			
Underground Gas Storage	0.42	0.03			
Processing	0.03				
Other	0.06				
	25.52				
Source: Gazprom Environmental Report 2020, p.59					
Gazprom's GHG Emissions by Gas and Source Category 2020, mtCO2e					
	Total	CO2	CH4		CH4 in mt meth
GHG Total	100.97	75.45	25.52		1.0208
Stationary fuel combustior	68.7	68.7	0		0
Flaring	2.26	2.18	0.08		0.0032
Fugitive Emissions	25.44	0	25.44		1.0176
Other Industrial Processes	4.47	4.47	0		0
Air Transport	0.07	0.07	0		0
Railway Transport	0.03	0.03	0		0
Gazprom Group Gas Business Companies mtCO2e					
	2016	2017	2018	2019	2020
CO2	70.1	85.1	92.5	92.1	80.4
Methane*	37.6	33.5	32.9	33.2	25.9
TOTAL CO2e	107.7	118.6	125.4	125.3	106.3
Methane mtCH4	1.504	1.34	1.316	1.328	1.036
Gazprom in Figures 2016-20, p.95					
*conversion factor of 25 applied to CO2e figure, Source: Gazprom in Figures 2016-					

Associated Gas Utilisation					
	2016	2017	2018	2019	2020
Gazprom Group					
PJSC		98.4	97.7	98.3	98.2
Sakhalin Energy		97	979.4	98	97.2
Gazprom Neft		76.2	78.3	89	91.1
Source: Gazprom Sustainability Report 2020, pp.131-2					

Novatek Emissions					
METHANE tonnes	2018	2019	2020		
Production facilities	7163	5913	8391		
Processing facilities	102	88	84		
processing and production of LNG t/mmboe	13.6	10.44	14.44		
LNG PRODUCTION tCO2e per ton of LNG	0.27	0.26	0.24		
Associated gas utilisation rate	97.1	83.3	96.2		
Source: Novatek Sustainability Report 2020, p.101 and 153					

Appendix 6: The BEIS/DEFRA methodology for estimating methane emissions

A number of sources use a methodology derived by UK government departments for methane emission estimation. A Shell press release for carbon-neutral LNG states:[184]

> ' … the DEFRA (UK Department for Environment, Food and Rural Affairs) conversion rates to calculate LNG emissions needed to be offset for Scope 1, 2 and 3. According to the 2020 DEFRA conversion rate, 1 tonne of LNG emits approximately 3.42 tonnes of CO_2e across the value chain, including end use. End use refers to combustion, which comprises about 2.54 tonnes of the total 3.42 tonnes of well-to-wheel emissions. The remaining emissions of 0.88 tonnes are across the value chain from exploration and production to transportation and regasification.'

The (DEFRA now) Department for Business Energy and Industrial Strategy (BEIS) data are for sources of imports of LNG into the UK using emissions data taken from reports by Exergia (and others) for the European Commission.[185] Exergia's interim report was published in October 2014 with data from around 2012, and a project executive summary in 2015.[186] The report contains a detailed examination of all the major EU pipeline and LNG value chains by different European regions but:

- the study notes the difficulties of obtaining data for many countries and supply chains;
- it provides averages for the EU from a dataset which is nearly 10 years old;
- some of the individual supply chains have changed significantly both in physical terms and in relative importance, for example, delivery routes for Russian gas have changed significantly and at that time there were no US LNG exports.

For the BEIS publications it might be thought that more current data would be required. But for calculations of emissions from carbon-neutral LNG cargos mainly delivered to Asia, the use of factors for natural gas and LNG being delivered to the UK based on a dataset which is nearly a decade old, is extremely unsatisfactory.

[184] Shell (2021a) note 2.
[185] BEIS (2021), Para 2.18, and Table 4.
[186] Exergia (2014) and Exergia (2015).