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Comparative GHG Footprint Analysis for European and Asian Supplies of USLNG, Pipeline Gas, and Coal

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INTELLIGENCE THAT WORKS

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1. INTRODUCTION AND SUMMARY

The BRG Energy & Climate practice (BRG E&C) has undertaken an independent life cycle analysis (LCA) of greenhouse gas (GHG) emissions of US liquefied natural gas (USLNG) and competing fossil fuels used for power generation in 13 destination markets.[1] Under development since 2021, this analysis uses a comprehensive model constructed by BRG E&C to regularly quantify the GHG emissions volumes and intensity of the LNG and competing fuel supply-chains at a systemic level for major trade corridors.[2] The model utilizes rigorous, analytic LCA methodology and continuously updated data and information from the best available sources.[3]

GHG EMISSIONS INTENSITY

GHG emissions intensity is generally defined as the amount of GHG emissions per the functional unit of a product. As a metric it is increasingly used to provide an "apples to apples" comparison between the emissions of different supply chains or origins of the same product. GHG emissions intensity metrics are also used in proposals for emissions taxes and fees.

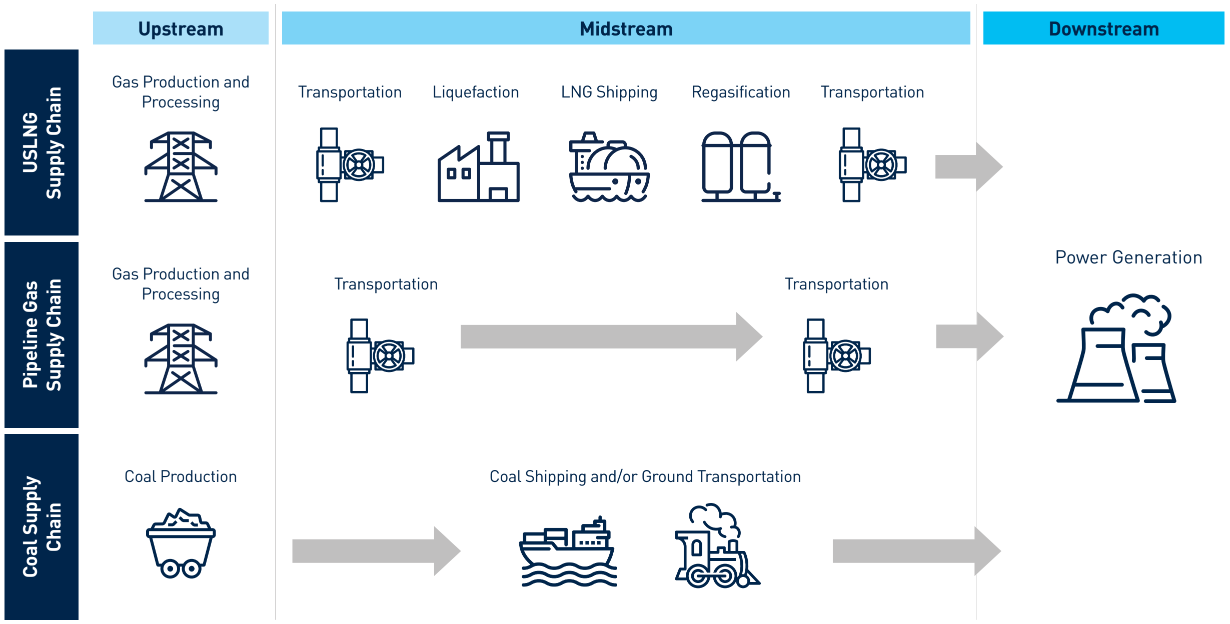
In our analysis, we define the GHG emissions intensity of different fuels as the amount of GHG emissions in kilograms (kg) emitted throughout the supply chain to produce one megawatt hour (MWh) of electricity in each destination country.

Scope of Analysis

The LCA presented in this report focuses on two key GHGs—carbon dioxide (CO2) and methane (CH4), collectively the "GHGs"—and evaluates their emissions volumes and intensity for the full supply chains (Figure 1) of USLNG, Pipeline Gas, and Coal (collectively "Primary Fuels"). Each supply chain spans from upstream production or extraction, through midstream infrastructure and/or shipping, to downstream combustion in power generation in the 13 European and Asian end markets. The destination markets are as follows:

- **Europe:** France, Germany, Italy, Netherlands, Poland, Spain, Türkiye, and United Kingdom (UK)
- **Asia:** China, India, Japan, South Korea, and Taiwan

FIGURE 1: SCOPE OF SUPPLY CHAIN GHG ANALYSIS



1 We estimate the GHG emissions intensity of USLNG imports, pipeline gas imports, and coal 2022 supply mix (including imports and domestic production). This work is underwritten by The US LNG Association (trading under the global brand name "LNG Allies") and the American Exploration and Production Council (AXPC).

2 As such, this analysis does not analyze specific supply chains for individual companies or infrastructure, but rather can be used as a benchmark for such analysis.

3 This LCA is based on the latest available emissions information, which is for calendar year 2022. Our approach utilizes reported emissions data wherever publicly available and employs emission factors and estimations only to fill gaps in publicly available data. The data was gathered from reputable sources among government agencies and multilateral organizations.

As illustrated in Figure 1:

- The "upstream" segments include production and processing for USLNG and Pipeline Gas and mining for Coal.
- For USLNG routes, the "midstream" segments include transportation from production sites to liquefaction plants, the liquefaction process, shipping to destination countries, regasification, and pipeline transportation from import border to power station in the destination country. For Pipeline Gas import routes, "midstream" represents transportation to the export border and from the import border to power stations. For Coal supplies, "midstream" represents transportation via rail or ship from the production site to the import border and from there to power stations.
- For all Primary Fuels, the "downstream" segment represents natural gas or coal consumption/combustion in the power sector of each destination country.

The analysis used the most up to data available data (generally from 2022) and converted CH_4 emissions to a CO_2 equivalent (CO_2e) basis using the 20-Year global warming potential (GWP20) of CH_4 relative to CO_2.[4] As explained in Section 3, we used GPW20 as the appropriate, "fit for purpose" metric to address the urgency of achieving substantial GHG reductions over the coming few decades, as compared to GWP100, which is appropriate for longer-term analysis.

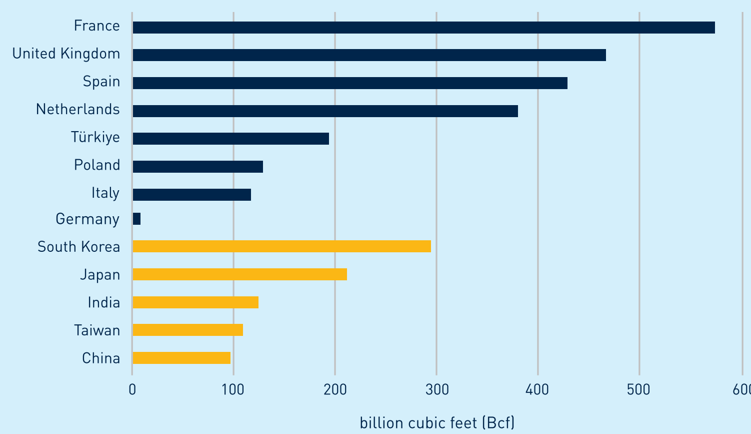
For each of the 13 destination markets covered in this report, the full life cycle GHG emissions of each competing fuel for electric power generation is analyzed as follows:

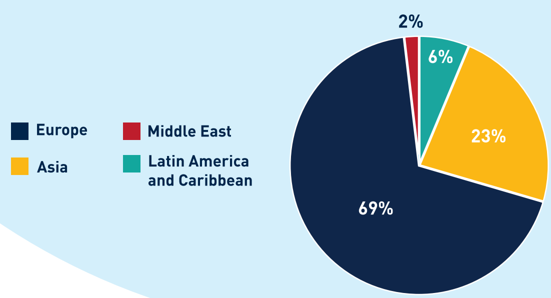
- **Imports of USLNG:** CO_2 and CH_4 emissions from feed-gas production in the United States through processing, pipeline transportation, LNG liquefaction, LNG tanker shipping, LNG regasification, downstream gas transport, and combustion for power generation.
- **Imports of Pipeline Gas (where available):** CO_2 and CH_4 emissions from the production, processing, transport, and combustion for power generation.[5]
- **Coal supplies**: CO_2 and CH_4 emissions from the production, processing, transport, storage, shipping (where relevant), and combustion for power generation.

WHY THESE 13 DESTINATION COUNTRIES?

USLNG exports from the contiguous 48 states began in February 2016 and reached a 2022 high of 11.75 billion cubic feet per day (Bcf/d) in March 2022. In 2022 USLNG cargoes went primarily to Europe (69%) and Asia (23%) with only small volumes flowing to the Latin America and the Caribbean (6%) and the Middle East (2%) (see Figure 2). The 13 markets analyzed in this study (eight in Europe and five in Asia, see Figure 2) represented 80% (3.099 Tcf) of all USLNG exports in 2022. The remaining volumes (0.76 Tcf) went to 21 other countries in the Americas, Asia, Europe, and the Middle East.

FIGURE 2: 2022 USLNG EXPORTS





4 GWP is a metric that represents the relative climate change impact of a GHG to its CO_2 equivalent impact on global warming over a specified period. GWP measures how much energy the emissions of 1 ton of a GHG will absorb over a given period, relative to the emission of 1 ton of CO_2. The larger the GWP, the more the GHG warms the earth compared to the same volume of CO_2 emissions over that period. Some international organizations use the GWP100 of 29.8x to account for CH_4 emissions on an equivalent GWP basis with CO_2. However, doing so on a 100-year basis would underestimate the near-term impact of CH_4 emissions on global warming over the coming few decades. See: Masson-Delmotte, V., et al.(eds.), *Climate Change 2021, The Physical Science Basis*, contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press: Cambridge, United Kingdom, and New York, NY, USA.

5 Upstream methane emissions for Pipeline Gas supply routes are taken by the IEA's Methane Tracker. IEA reports "Upstream includes all emissions from production, gathering, and processing on all onshore or offshore oil and gas facilities." See: https://www.iea.org/data-and-statistics/data-tools/methane-tracker (accessed March 2024).

Measurement of Fuel Supply Chain GHG Emissions

From mid-2021 through 2022, energy demand in Europe and Asia was driven primarily by the rebound in energy consumption following the deep downturn from the COVID-19 pandemic worldwide and the effects of the Russian energy curtailments before and after the invasion of Ukraine, which slashed Europe's energy supply, stimulated LNG imports, and led to a global LNG supply crunch and LNG price spikes worldwide.

Even during the energy security challenges of recent years, the climate change imperative has continued to produce significant decarbonization efforts in the electric power and industrial sectors. A critical initial requirement for GHG mitigation is the accurate estimation/measurement of emissions across fuel supply chains, including both CO2 and CH4.

Whereas governments and energy and industrial firms have been measuring and tracking CO2 and CH4 emissions for more than two decades,[6] there has been increasing focus on the material impact of CH4 emissions on the climate in recent years. When measured by the GWP20, the per-ton impact of CH4 is 82.5 times greater than the per-ton impact of CO2 emissions.[7]

Given the urgency of decarbonization in the next few decades, international organizations have called for coordinated efforts to measure/mitigate CH4 emissions in oil and gas production, coal mining, maritime transport, power generation, and industry. As a result, national, regional, and international efforts are targeting CH4 emissions; this is one reason why natural gas producers and consumers are actively and aggressively addressing CH4 emissions.[8]

The focus on developing accurate measurements of CH4 emissions, in turn, is driving the rapid development of measurement technologies such as ground monitors using gas spectrometers, aerial drones equipped with onboard gas analyzers, manned aircrafts with emissions cameras, and satellite emissions monitoring. Measurement technologies that operate at a large scale, such as drones, aircraft, and satellites, are often referred to as "top-down" approaches. They vary in their ability to detect emissions at different temporal and spatial scales due to differences in their detection limits, meteorological conditions, and deployment frequency.

Satellite emissions monitoring involves sophisticated data analytics and processing to analyze oil and gas operations relatively consistently across national boundaries and international jurisdictions. This is a new and rapidly evolving area for emissions measurement at a systemic level, comparable to the scope of this study.

Evaluating energy supply through the lens of GHG emissions intensity provides an important step toward the decarbonization of energy systems. Robust methodologies, enhanced data quality, and rigorous measurement and analysis of GHG emissions are crucial to achieving a comprehensive picture of the GHG footprint of energy supply chains overall and along each supply chain segment.

6 The Kyoto Protocol, which was adopted in 1997 and entered into force in 2005, defined which GHGs to include in carbon accounting frameworks (including CO2 and CH4) and established a monitoring, review and verification system for the participating parties. (See: https://unfccc.int/kyoto_protocol#:~:text=In%20short%2C%20the%20Kyoto%20Protocol,accordance%20with%20agreed%20individual%20targets.)

7 The International Energy Agency (IEA) reported in their its annual global methane tracker report update, in March 2024, that global CH4 emissions from the energy sector remained near a record high in 2023. IEA Methane Tracker, (March 2024).

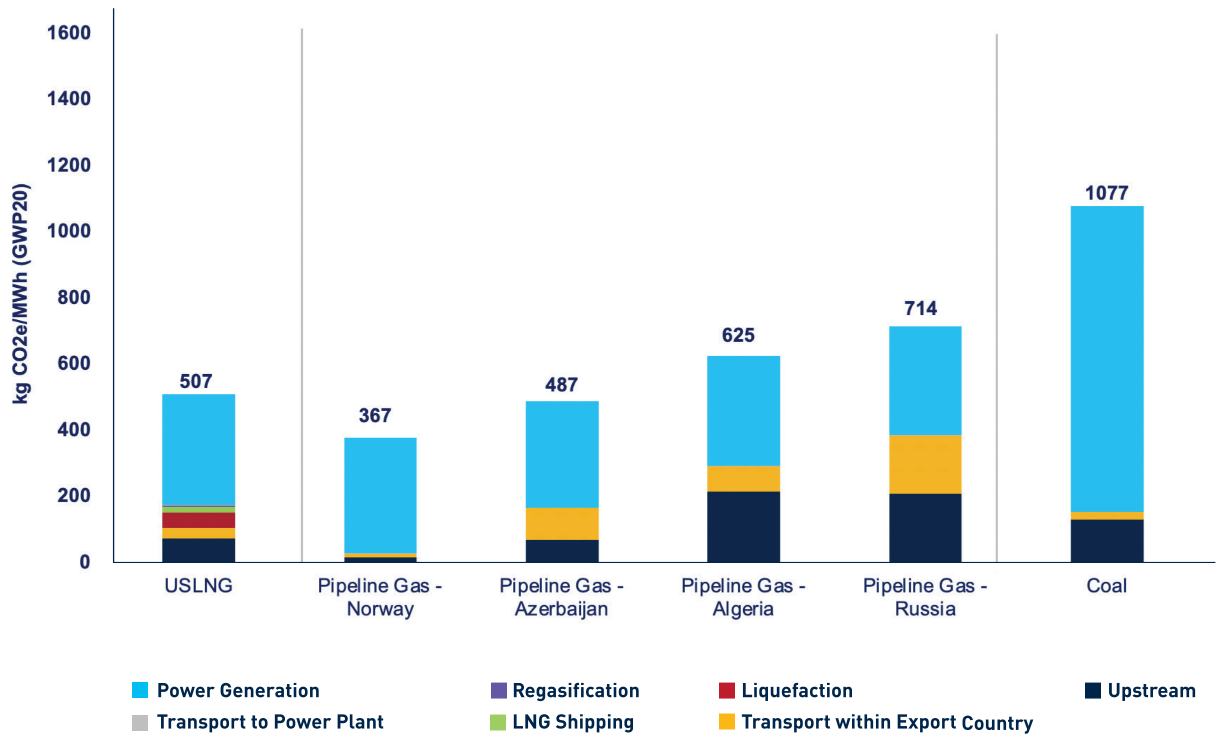
8 CH4 (methane) is the principal component of natural gas, and producers and consumers have a financial incentive to minimize CH4 losses at all segments of the supply chain.

2. SUMMARY RESULTS

To provide a baseline to evaluate the challenges outlined above, this study provides an integrated analysis of CH4 and CO2 emissions across leading fuel supply chains (USLNG, Pipeline Gas, Coal), using the latest available data from reputable sources among government agencies and multilateral organizations, in a detailed methodology designed to accurately compare the GHG intensity of these fuel imports and supplies for power generation in the destination countries.

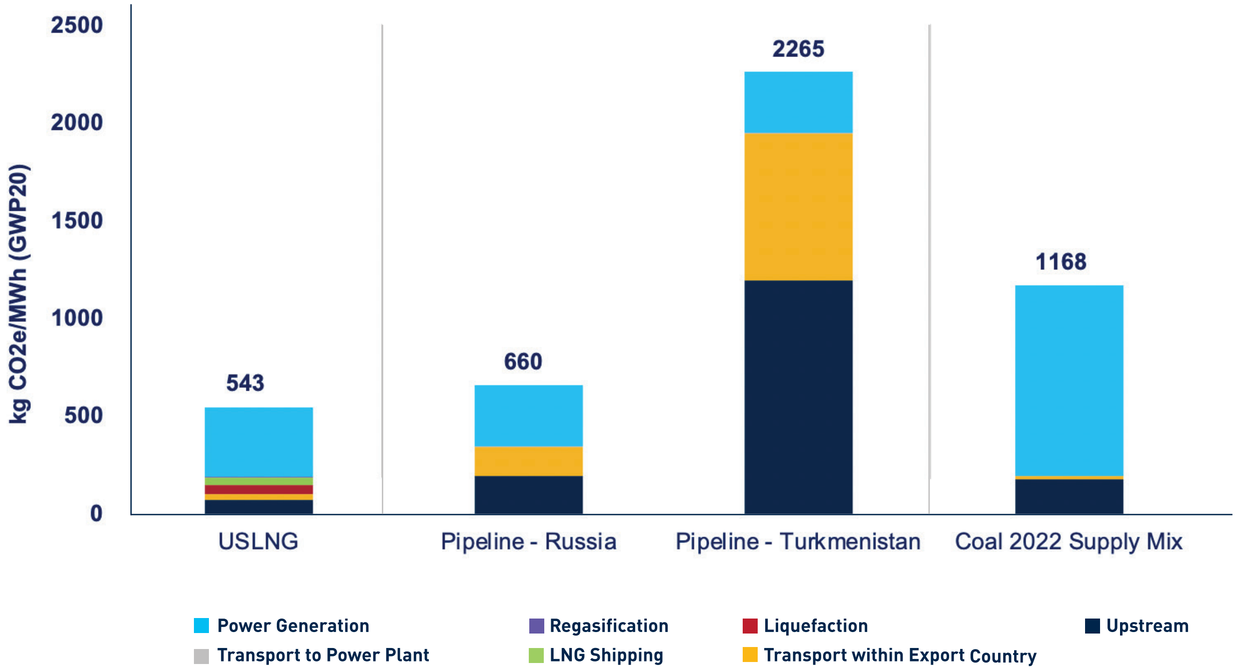
Figure 3 and Figure 4 present our results of the average full supply chain GHG emissions intensity of USLNG imports, Pipeline Gas imports, and Coal supplies to Europe and Asia, respectively.[9]

FIGURE 3: AVERAGE GHG EMISSIONS INTENSITY OF USLNG, PIPELINE GAS IMPORTS, AND COAL SUPPLIES TO EUROPE



9 The GHG emissions intensity of each Primary Fuel supply route corresponds to the simple average of GHG emissions intensity of routes to the following destinations: Netherlands, Germany, United Kingdom, Italy, Spain, France, Türkiye, and Poland ("Europe") and China, India, Japan, Korea, and Taiwan ("Asia"). USLNG represents a simple average of GHG emissions intensity of USLNG from three main production areas: Gulf Coast, East Coast, and South Texas. Coal represents a simple average of GHG emissions intensity of the 2022 coal supply mix and domestic production for each destination. Pipeline Gas represents a simple average of GHG emissions intensity of the main origins of supply.

FIGURE 4: AVERAGE GHG EMISSIONS INTENSITY OF USLNG, PIPELINE IMPORTS, AND COAL SUPPLIES TO ASIA



WHAT IS DIFFERENT ABOUT THIS LIFECYCLE ANALYSIS?

On balance, the findings of this study differ significantly from the results of other recent studies, which purport to show that the GHG emissions intensity of USLNG is *greater* than that of coal when used to produce electricity. Our LCA differs from these studies in two principal respects:

- **Methodology:** This study employs a bottom-up methodology to arrive at a comprehensive comparison of the emissions intensity of the primary fuels for a specific historical time period (2022) and specific trade corridors and supply chain segments. By comparison, the other studies analyze aggregated emissions information to develop general *theoretical* conclusions about the comparative GHG footprint of USLNG and coal supplies, *without* specific evaluation of regional, trade route, or timeframe distinctions.

- **Data Used:** To the greatest extent possible, we have used the most up-to-date emissions data and reported/measured emissions for each supply chain segment and delivery route. Other studies rely primarily on emission factors, many of which are outdated, as well as aggregated emission intensity results for gas and coal supply chains derived from other *theoretical* studies.

The results presented in Figure 3 and Figure 4 indicate that the average GHG emissions intensity of:

- **Coal** was over twice as high as USLNG in both Europe and Asia.
- **Pipeline Gas in Europe** was about three-quarters of USLNG for gas coming from Norway but more than a third higher than USLNG for gas coming from Russia.
- **Pipeline Gas in Asia** was more than four times higher than USLNG in the case of pipeline gas from Turkmenistan and slightly higher than USLNG for pipeline gas from Russia.

Figure 5 and Figure 6 present the breakdown of average GHG emissions intensity per Primary Fuel supply chain by CH4 and CO2 in Europe and Asia, respectively.

FIGURE 5: AVERAGE CH4 AND CO2 EMISSIONS INTENSITY ACROSS THE PRIMARY FUEL SUPPLY CHAINS TO EUROPE

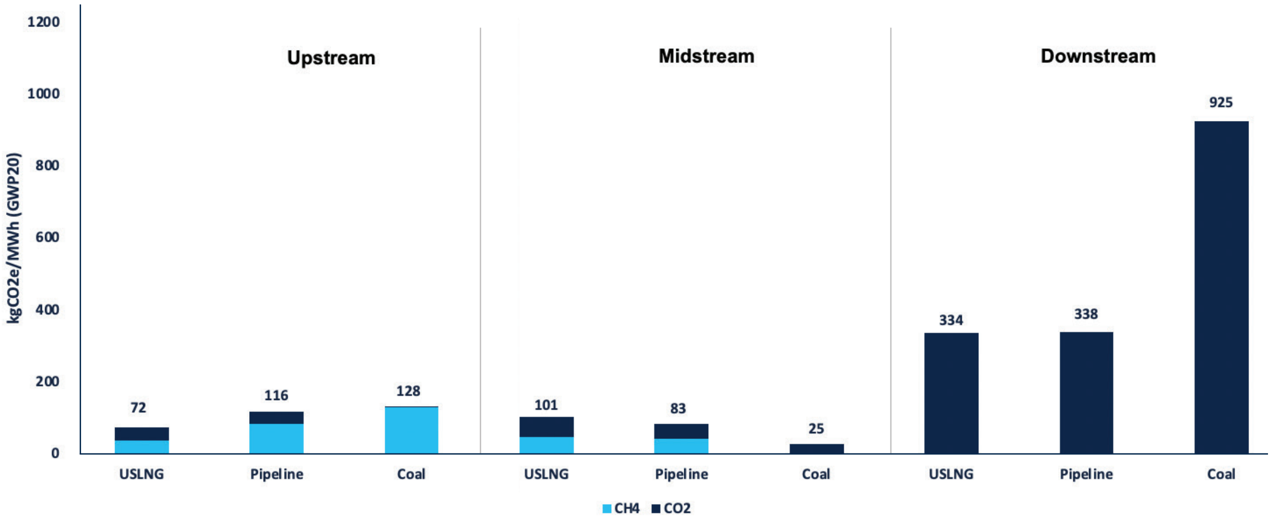
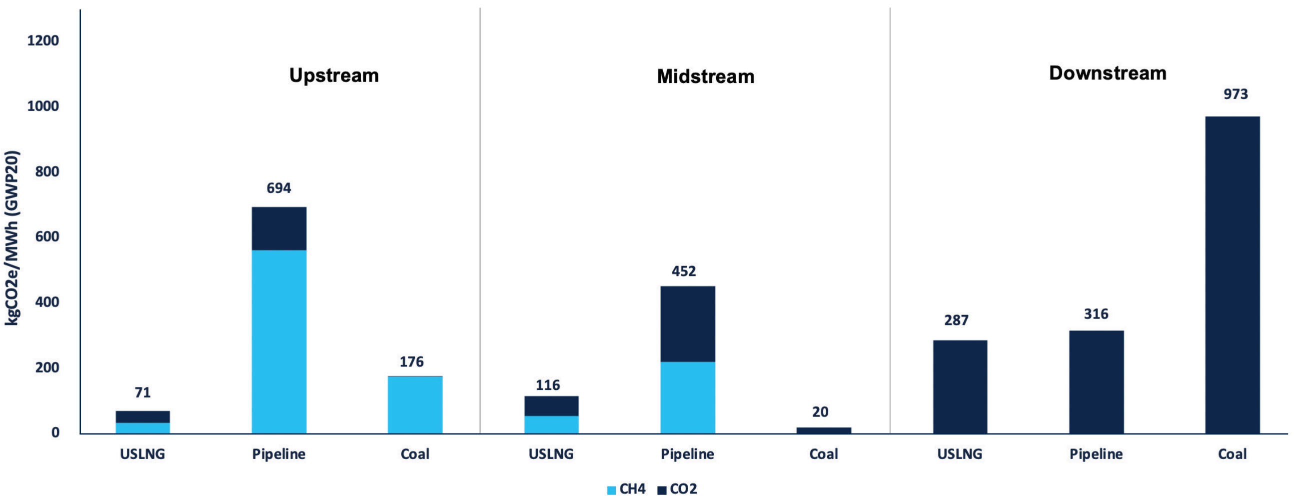


FIGURE 6: AVERAGE CH4 AND CO2 EMISSIONS INTENSITY ACROSS THE PRIMARY FUEL SUPPLY CHAINS TO ASIA



3. LIFECYCLE COMPARISON OF PRIMARY FUELS IN GLOBAL MARKETS

Approach

This study combines commonly used methodologies for lifecycle emissions analyses with up-to-date publicly available data on reported emissions and emission factors to deliver a systemic evaluation of the GHG emissions intensity of Primary Fuels supply chains or trade corridors into the major USLNG importing markets.[10]

We calculate the GHG emissions intensity of each segment of the supply chain for all Primary Fuels, analyzed and presented in terms of kilograms of CO2e per megawatt hour (MWh) of electricity generation (kg CO2e/MWh). This metric represents the amount of CO2e emitted throughout each segment of the supply chain, from upstream production to final combustion for power generation, for each MWh of electricity generated. There are two important elements to note on the chosen metric:

- **Functional unit:** Using the 1 MWh of electricity generated from each different fuel in each different destination as the "functional unit," the analysis accounts for the different chemical characteristics of gas and coal, as well as the thermal efficiency characteristics of the power generation fleet of each destination country, namely the amount of energy used by a gas and coal power generation unit to produce 1 MWh of electricity (also known as a power generation "heat rate"). Other functional units are commonly used to present full supply chain GHG emissions, such as MMBtu of fuel supply, and we present our country-by-country results in kg CO2e per MMBtu of fuel supply in APPENDIX D.

- **CO2 equivalence:** In our analysis we calculate the CO2 and CH4 emissions in each segment of the supply chain. To account for these GHGs in an equivalent manner, we convert the CH4 emissions to their CO2 equivalent using the 20-year global warming potential (GWP20) of CH4 relative to CO2. The GWP20 of CH4 used in this study is equal to 82.5, based on the latest report of the Intergovernmental Panel on Climate Change (IPCC).[11] In this analysis, we use GWP20 for CH4 emissions because we consider GWP20 as "fit for purpose" given the urgency of achieving substantial GHG reductions over the coming few decades, as compared to GWP100, which is more appropriate for longer-term analyses.

IMPORTANCE OF DATA QUALITY AND CONSISTENCY

The results of this study (like all LCAs) depend on the accuracy and consistency of the underlying emissions data for Primary Fuels that are available from public sources. To date, such data include a mix of reported emissions and estimated emission factors.

The quality of GHG emissions measurement for specific energy production equipment and infrastructure across supply chains has been improving at a significant pace due to the development and proliferation of advanced technologies for ground-level measurement and monitoring of GHGs with advanced sensors installed on critical equipment and/or aerial drones.

Further, for wider-scale national and international systemic analysis, several independent entities already offer (or will soon provide) satellite imaging of GHG emissions, enabling quantification of CH4 emission footprints of production areas, asset clusters, and transportation infrastructure across regions and countries.

Within a few years, accessing and analyzing such data may improve emissions measurements across regions, jurisdictions, and international boundaries to help level the playing field by providing for standardized quantification of the GHG emissions intensity of all fuel supply chains worldwide.

10 The most recent data on CH4 and CO2 emissions used in this study are from 2022. There are instances where 2022 data were not available at the time of writing this report. For example, the latest update of emission factors for transport of natural gas was in 2019. In cases where 2022 data were not available, we used the next most recent data. See APPENDIX A for details of our data sources.

11 Forster, P., et al., "The Earth's Energy Budget, Climate Feedbacks, and Climate Sensitivity," in Masson-Delmotte, V., et al. (eds.) (2021), p. 1017.

Methodology

USLNG and Pipeline Gas imports

For the calculation of GHG emissions intensity throughout the USLNG and Pipeline Gas supply chains, we used the commonly applied "mass balance" methodology,[12] which is based on the following principles:

- As gas flows through each part of the supply chain, from production all the way to final combustion for power generation, it is partially consumed to supply energy and/or leaked, vented, or flared, such that the mass of natural gas decreases at each stage.
- GHG emissions depend on the quantity of gas flowing through each part of the supply chain.

The starting point of our methodology is the quantity (mass) of natural gas consumed at the power station of each destination country to generate 1 MWh of electricity, based on country-specific averages of powerplant heat rates. Following the principles outlined above, we work backward to calculate the gas volumes from each preceding segment of the supply chain based on the chemical properties of natural gas and the losses incurred at each supply chain segment (i.e., the amount of gas consumed at each segment and/or leaked, flared, and/or vented).

Table 1 and Table 2 describe the methodology used in each segment of the USLNG and Pipeline Gas supply chains, respectively. In each segment, we calculated the GHG emissions intensity in kgCO2e/MWh of that segment, considering the quantity of gas necessary to produce 1 MWh of electricity in the destination country. Data sources used in our analysis are presented in APPENDIX A.

TABLE 1: USLNG SUPPLY CHAIN METHODOLOGY

Supply Chain Segment	Methodology
Upstream Production and Processing	We use data from 2022 on GHG emissions during natural gas production and processing, in the four main US gas production basins: Marcellus-Utica, Eagle Ford, Permian, and Haynesville. We estimate the origin and transportation routes of feed-gas, and we apportion the emissions from these basins to the seven US large liquefaction plants (Sabine Pass, Corpus Christi, Freeport, Cove Point, Elba Island, Cameron, and Calcasieu Pass). We aggregate the CH4 and CO2 emissions of the seven liquefaction plants into three main exporting areas: • Gulf Coast Louisiana: Sabine Pass, Cameron, and Calcasieu Pass • South Texas: Corpus Christi and Freeport • East Coast: Cove Point and Elba Island
Gas Transport from Production to Liquefaction	We calculate CH4 and CO2 emissions based on reported emission factors and adjustments for the distances covered in each route.
Liquefaction	We calculate the CH4 and CO2 emissions during liquefaction based on emission factors.
Shipping	We calculate CH4 and CO2 emissions for LNG shipping based on actual emissions measurements adjusted to account for the number and type of actual LNG carrier voyages that took place in 2022 between loading ports in the United States and discharge ports in each of the 13 countries analyzed.
Regasification	We calculate the CH4 and CO2 emissions during regasification based on emission factors and adjusted for the heat rate of gas power generation at each destination country.
Gas Transport to Powerplant	Following the same methodology used for the transportation from production site to liquefaction plant, we use reported emission factors and adjust for distances covered in each route for downstream gas transportation from regasification to the powerplant.
Gas Combustion for Power Generation	In the power generation sector, we consider only CO2 emissions from the combustion of natural gas. We calculate CO2 emissions considering the specific heat rate of the power generation sector of each destination country in 2022.

12 Rosselot, Kirsten, David T. Allen, & Anthony Y. Ku, "Comparing greenhouse gas impacts from domestic coal and imported natural gas electricity generation in China," *ACS Sustainable Chem. Eng.*9:26 (2021), pp. 8759–8769.

TABLE 2: PIPELINE GAS SUPPLY CHAIN METHODOLOGY

Supply Chain Segment	Methodology
Upstream Production and Processing	For Pipeline Gas supplies to the destination countries, we first select the main origins of supplies to each country, focusing on gas imports in 2022 (where applicable). For Europe, the main sources of Pipeline Gas supplies in 2022 were Russia, Norway, Algeria, and Azerbaijan. For Asia, China imported Pipeline Gas from Turkmenistan and Russia in 2022. We calculate the CH4 emissions during gas production, CO2 emissions from flaring, and CO2 emissions that occur in the processing stage in each supply origin country.
Gas Transport from Production Border	We calculate CH4 and CO2 emissions based on reported emission factors and adjust for the distances covered in each route.
Gas Transport from Border to Powerplant	Following the same methodology used for the transportation from production site to export border, we calculate CH4 and CO2 emissions based on reported emission factors and adjust for the distances covered in each route.
Gas Combustion for Power Generation	Following the same methodology used for the USLNG supply chain routes, we calculate CO2 emissions for power generation based on our calculation of theconsidering country-specific heat rates of gas power generation in 2022.

Coal Supply Chain

To calculate total GHG emissions throughout the full supply chain for Coal, we analyzed each segment separately, based on the amount of Coal consumed to generate 1 MWh of electricity in each destination country. The main GHG emitted during the Coal-mining phase is CH4, whereas the main GHG emitted during the transportation and combustion phases is CO2. Our methodology for the calculation for Coal is presented in Table 3.

TABLE 3: COAL SUPPLY CHAIN METHODOLOGY

Supply Chain Segment	Methodology
Upstream Coal Mining	To calculate CH4 emissions for the 2022 Coal supply mix, we performed a comprehensive Coal supply analysis for each destination country to determine the amount and origin of imported Coal and the amount of domestically produced Coal.[13] Then, we used data on CH4 emissions from coal mining in each coal supply source country to quantify the CH4 emissions intensity of each coal supplier for each destination country.
Coal Transport to Export Border	Because inland rail is the most common means of transportation for coal,[14] we consider that coal is primarily transported by rail from the mine to the export border of the supply source countries. We calculated CO2 emissions based on emission factors for rail transport adjusted for distances covered in each route.
Coal Transport from Origin Export Border to Destination Import Border	We estimated the shipping emissions of transporting coal overseas based on reported CO2 emission factors for dry bulk carriers.
Coal Transport from Import Border to Power Station	Using the same approach employed for CO2 emissions for transportation from the mine to the export border, we estimated CO2 emissions based on emission factors for rail transport adjusted for the distances covered in each route.
Coal Combustion for Power Generation	For emissions from power generation, we calculated the CO2 emissions from the coal combustion based on the specific heat rate of the coal power generation sector of each destination country in 2022.

13 Coal supply mix information by country comes from UN Comtrade. Due to a lack of available information on Taiwan's coal supply mix, Japan and South Korea's coal supply mixes are averaged and then scaled based on energy consumption from Ember to create a representative coal supply mix for Taiwan. The UN Comtrade database we used does not differentiate between thermal and metallurgical coal imports. We assume that all imported coal is used in power generation.

14 See Skillings Mining Review, "The Ultimate Guide to Coal Mining and Transportation: Processes, Techniques, and Environmental Impact" (May 2, 2023). https://skillings.net/the-ultimate-guide-to-coal-mining-and-transportation-processes-techniques-and-environmental-impact/

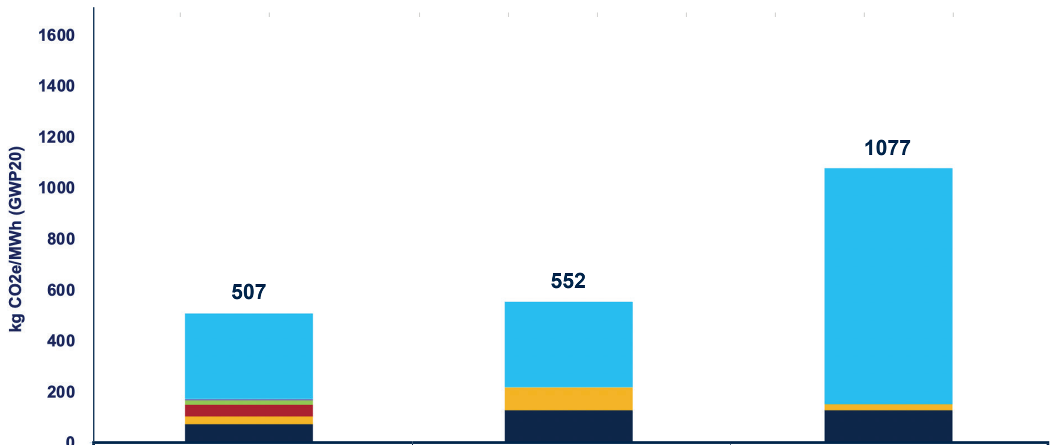
4. RESULTS AND CONCLUSIONS

GHG Emissions Intensity of USLNG, Pipeline Gas, and Coal Supplies to Europe and Asia

This section presents our aggregated results on the GHG emissions intensity of Primary Fuels in the European and Asian destination countries we analyzed. We present the distribution of GHG emissions intensity by supply chain segment and the breakdown of CH4 and CO2 emissions intensity in each supply segment.

Figure 7 and Figure 8 compare the average GHG emissions intensity for USLNG, Pipeline Gas, and Coal imports and supply in Europe and Asia, respectively.[15]

FIGURE 7: COMPARISON OF AVERAGE GHG EMISSIONS INTENSITY OF PRIMARY FUELS IN EUROPE (GWP20)



	USLNG	Pipeline Gas	Coal
Power Generation	334	336	925
Transportation to Power Plant	1	2	1
Regasification	4		
LNG Shipping	17		
Liquefaction	47		
Transport within Export Country	31	90	24
Upstream	72	128	128
Total	507	552	1077

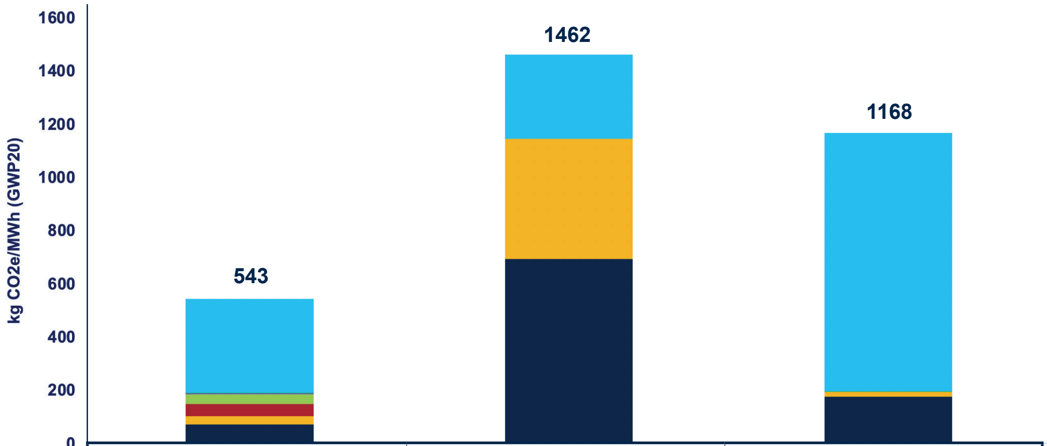
The results in Figure 7 indicate that for power generation in Europe the average GHG emissions intensity of USLNG was 507 kgCO2e/MWh, which was:

- 53% lower than the 1,077 kgCO2e/MWh for Coal.
- 8% lower than the 552 kgCO2e/MWh for the main sources of pipeline imports (which vary widely).

More specifically, on average, the GHG emissions intensities of USLNG are 29% and 19% lower than that of Pipeline Gas from Russia and Algeria, respectively, but 35% and 4% higher than that of Pipeline Gas from Norway and Azerbaijan, respectively.

15 In the following figures, USLNG represents an average of GHG emissions intensity of USLNG from three main production areas: Gulf Coast, East Coast, and South Texas. The GHG emissions intensity of each Primary Fuel supply route corresponds to the simple average of GHG emissions intensity of routes to the following destinations: Netherlands, Germany, United Kingdom, Italy, Spain, France, Türkiye, and Poland ("Europe"); and China, India, Japan, Korea, and Taiwan ("Asia"). For USLNG and Pipeline Gas, we consider the GHG emissions intensity of imports to the countries analyzed. For Coal, we consider the GHG emissions intensity of the 2022 supply mix in each destination, including domestic production. The segment "Transport within Export Country" includes emissions from shipping in cases of overseas Coal transport.

FIGURE 8: COMPARISON OF AVERAGE GHG EMISSIONS INTENSITY OF PRIMARY FUELS IN ASIA (GWP20)



	USLNG	Pipeline Gas	Coal
Power Generation	352	316	973
Transportation to Power Plant	2	1	0
Regasification	4		
LNG Shipping	36		
Liquefaction	47		
Transport within Export Country	31	451	19
Upstream	71	694	176
Total	543	1462	1168

By comparison, the average results in Figure 8 indicate that for power generation in Asia, the average GHG emissions intensity of USLNG imports is 543 kgCO2e/MWh, which was:

- 53% lower than the 1,168 kgCO2e/MWh for Coal.
- 63% lower than the 1,462 kgCO2e/MWh for the GHG emissions intensity of pipeline imports.[16]

Figure 7 and Figure 8 also indicate that the GHG emissions intensity of Coal combustion for power generation (comprised of CO2 only) was almost triple that of gas in both Europe and Asia on average, clearly demonstrating the superior combustion efficiency of natural gas compared to Coal and the higher heat rates of natural gas power stations compared to Coal power stations. On average for natural gas, Europe and Asia had similar average heat rates, and therefore similar GHG emission intensity levels. The heat rate for Coal power generation in Asia was on average lower than that in Europe, resulting in higher GHG emissions intensity in Asia as compared to Europe for this supply chain segment.

16 The GHG emissions intensity of Pipeline Gas in Asia exceeds U.S. LNG imports and even that of Coal supplies because of the very high CH4 emissions reported for the upstream and domestic transportation segment of Pipeline Gas from Turkmenistan to China (see APPENDIX C for detailed country results).

The average GHG emissions intensity across the supply chain segments also varied between the European and Asian destination markets. Figure 9 and Figure 10 present the average distribution of GHG emissions intensity along the upstream, midstream, and downstream supply chain segments for USLNG, Pipeline Gas imports, and Coal supplies to Europe and Asia, respectively.

Upstream represents production and processing for USLNG and Pipeline Gas and mining for Coal. Midstream represents transport from production, liquefaction, shipping to destination, regasification, and transport to power stations for USLNG. For Pipeline Gas, it represents transport from production to power stations. For Coal, it represents transport from mining sites via rail or ship and further transport to power stations.

FIGURE 9: AVERAGE GHG EMISSIONS INTENSITY ACROSS SUPPLY CHAIN SEGMENTS IN EUROPE

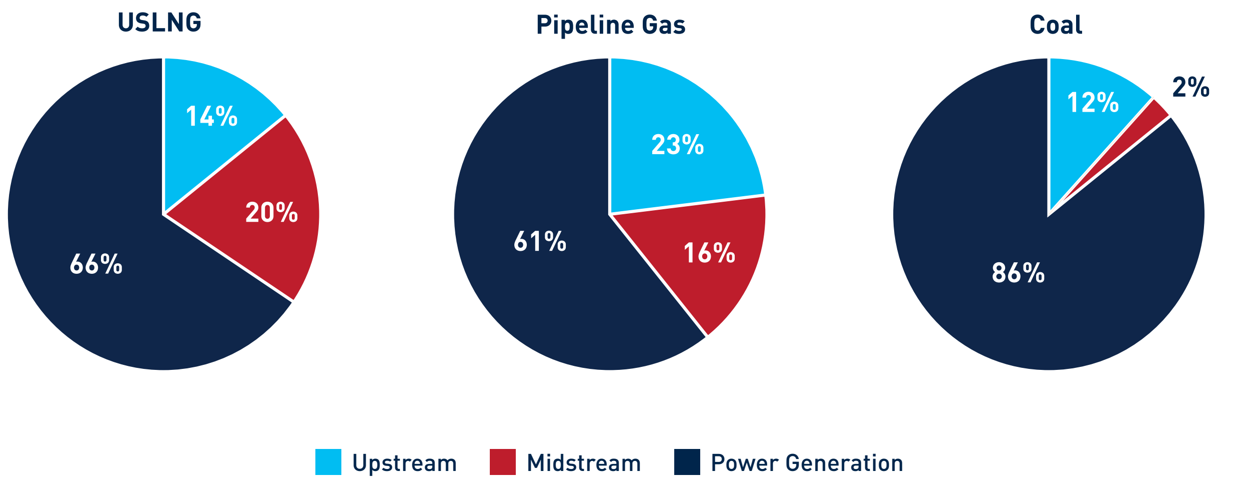


FIGURE 10: AVERAGE GHG EMISSIONS INTENSITY ACROSS SUPPLY CHAIN SEGMENTS IN ASIA

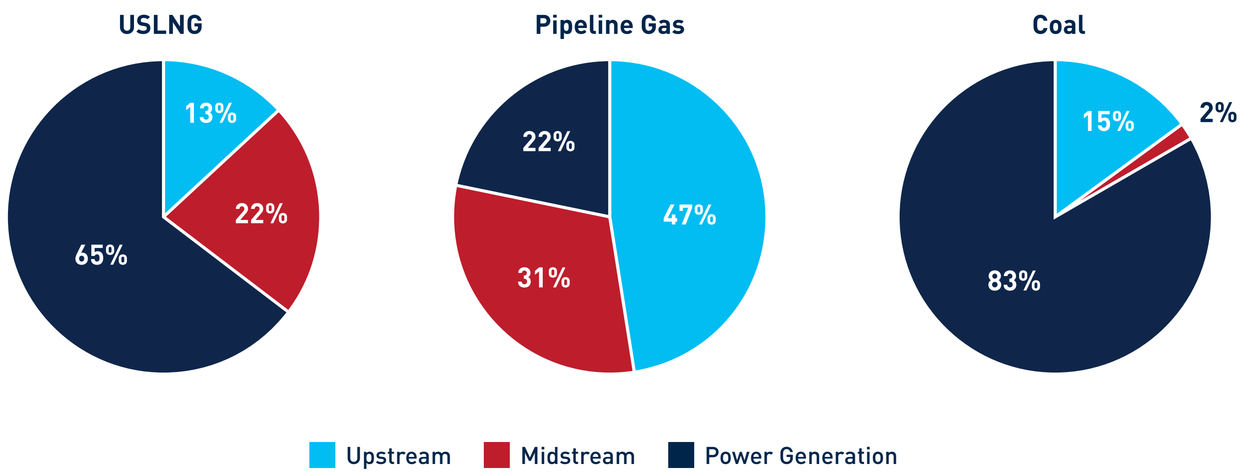


Figure 9 and Figure 10 indicate that:

- **USLNG:** For USLNG supply chains to Europe and Asia, some 65% of the GHG emissions intensity was concentrated in the power generation segment, with approximately 13% to 14% of emissions in upstream, and the remaining 20% to 22% in the midstream segment.
- **Pipeline Gas:** The average GHG emissions intensity across the supply chain of Pipeline Gas imports to European destinations was similar to that of USLNG imports, with about 61% of emissions intensity concentrated in the power generation segment, 23% in the upstream, and 16% in the midstream. In sharp contrast, almost 50% of the emissions intensity of Pipeline Gas imports to Asia was concentrated in upstream operations, 30% in the midstreamsegment, and 22% in power generation.
- **Coal:** For Coal supplies to Europe and Asia, the vast majority of GHG emissions intensity was concentrated in the power generation sector (86% and 83%, respectively), followed by 12% to 15% in upstream operations, and only 2% in the midstream segment. Nonetheless, CH4 emissions from Coal mining are a serious and often overlooked issue.

Figure 11 and Figure 12 present the average distribution of GHG emissions intensity by CH4 and CO2 in Europe and Asia, respectively.

FIGURE 11: AVERAGE CH4 AND CO2 ACROSS THE PRIMARY FUEL SUPPLY CHAINS TO EUROPE

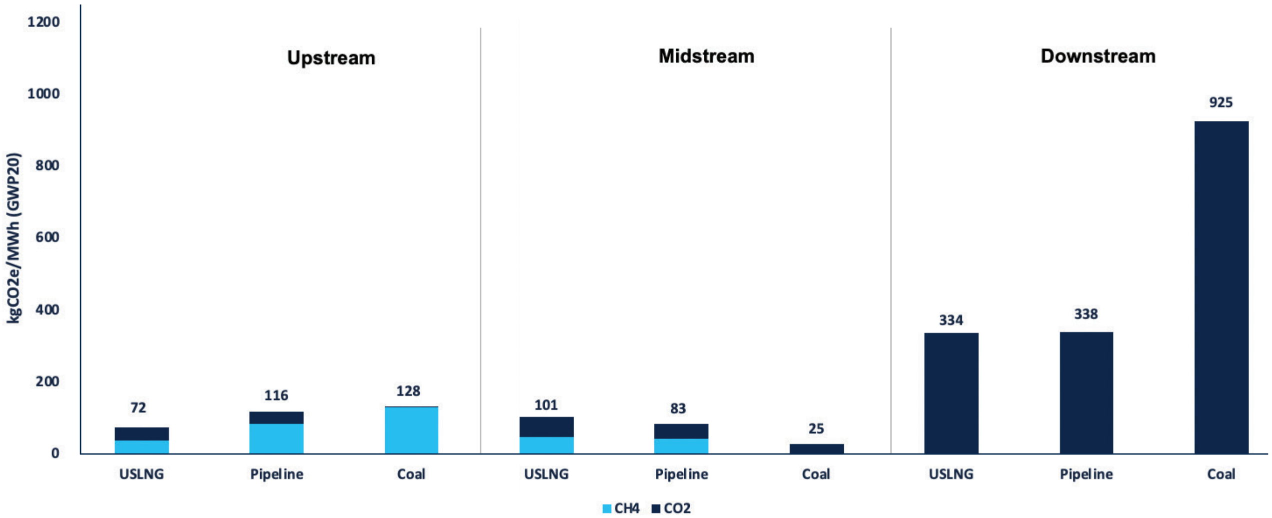


FIGURE 12: AVERAGE CH4 AND CO2 ACROSS THE PRIMARY FUEL SUPPLY CHAINS TO ASIA

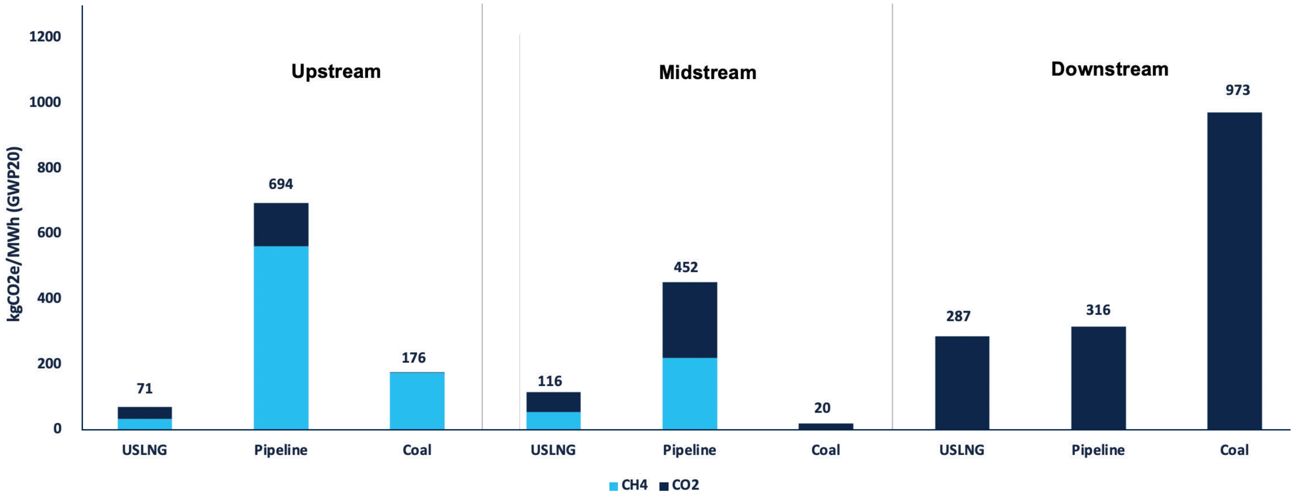


Figure 11 and Figure 12 suggest that on average for:

- **Upstream Segments**, the GHG emissions intensity of USLNG imports to Europe and Asia was roughly balanced between CH4 and CO2. By comparison, the GHG emissions intensity of Pipeline Gas imports to Europe and Asia was dominated by CH4 emissions from gas production and processing. Finally, the GHG emissions intensity of Coal supplies was 100% composed of CH4 emissions from coal mining.
- **Midstream Segments**, the GHG emissions intensity of USLNG and Pipeline Gas imports to Europe and Asia was balanced between CH4 and CO2. By comparison, the GHG emissions intensity of Coal supplies to Europe and Asia was dominated by CO2 emitted during combustion in transportation carriers (rail and/or vessels).
- **Downstream Segments** are dominated by CO2 emissions for all fuel supply chain routes, driven by substantial emissions from combustion in power generation stations, especially for Coal. Therefore, the downstream GHG emissions intensity comprises solely CO2 emissions.

COAL MINE METHANE EMISSIONS

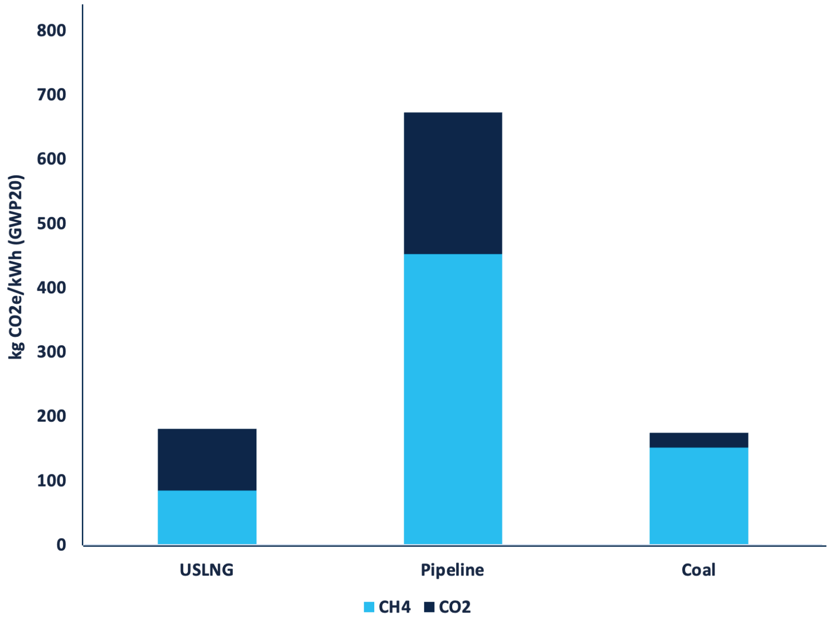
Accurate accounting for methane emissions in Coal mining is critical to developing a true "apples-to-apples" comparison of the GHG footprint of Coal supply chains as compared to Pipeline Gas and USLNG. Evaluating CH4-intensive coal-mining sectors of countries such as Indonesia, India, China, and Russia[17] is critical because Coal supplies from these countries constitute a very significant share of the fuels used for power generation in many Asian countries.

Figure 13 provides the global average of GHG emissions intensity breakdown into CO2 and CH4 for just the upstream and midstream segments of the supply chain (i.e., production, transportation, and delivery to the European and Asian border points of import) of Primary Fuel supplies.

Figure 13 indicates that in the GHG intensity of the fuel supply chains to border delivery points (i.e., excluding downstream transportation and power generation), CH4 emissions intensity represented on average:

- 47% of total emissions intensity in the USLNG routes
- 67% of total emissions intensity in the Pipeline Gas routes
- 87% of total emissions intensity in the Coal routes

FIGURE 13: UPSTREAM AND MIDSTREAM GHG EMISSIONS INTENSITY (GWP20)



17 Setiawan, Dody, & Chris Wright, "Uncovering Indonesia's hidden methane problem" (March 12, 2024). See also: Ember, "Methane leaks are super-charging the climate crisis" (March 2023). https://ember-climate.org/topics/coal-mine-methane/ (accessed March 2024).

Greenhouse Gas Emissions Savings

The comparison between the average GHG emissions intensity of USLNG imports and Coal supplies for power generation in the 13 European and Asian countries analyzed demonstrates the climate advantage of using USLNG instead of Coal in the leading foreign markets for USLNG.

Assuming that USLNG supplies are used to replace Coal-fired generation with natural gas generation, we calculated the total quantity of CO_2 and CH_4 emissions that are saved on average by delivering a single USLNG cargo to Europe and Asia.[18] Our results indicate that on average:

- In the eight European countries studied, a single cargo of USLNG to produce electricity would have saved from 174,000 to 469,000 tons of CO2e as compared to Coal-fired generation. The wide range of results reflects the different heat rates of power generation fleets in the destination countries and varying GHG emissions intensities of USLNG and Coal supply routes.
- In the five Asian nations examined, this equivalent range of GHG savings per average USLNG cargo was between 225,000 and 538,000 tons of CO2e.

Table 4 presents the potential range of GHG savings achieved by using USLNG imports to generate electricity instead of Coal in Europe and Asia.

TABLE 4: GHG SAVINGS FROM USLNG REPLACING COAL FOR POWER GENERATION[19]

Region	USLNG Imports in 2022 (MMtpa)	Corresponding Number of Cargoes	Range of Annual GHG Savings in 2022 (million tons CO2e)
Europe	50	665	116–312
Asia	18	241	54–130
Total	68	906	170–440

18 This analysis assumes that importers can use USLNG cargoes instead of Coal in the power generation sector, where the average LNG cargo contains 3.5 TBtu of energy.

19 Numbers may not add-up due to rounding.

Figure 14 illustrates the magnitude of potential annual savings using USLNG instead of Coal in the power generation sector of the countries analyzed.

FIGURE 14: POTENTIAL SAVINGS AND NUMBER OF CARS WITH EQUIVALENT CO2 EMISSIONS[20]

Annual GHG Savings (ktCO2e)

170,000 – 440,000

Number of Cars with equivalent annual CO2 emissions (millions)

153-397

Publicly Available Data

The results of this study largely depend on the accuracy and consistency of the underlying emissions data available from the leading public sources. To date, the leading sources of publicly available data on GHG emissions have established rigorous systems to encourage consistent data reporting, including a mix of reported emissions data and estimated *emission factors*. However, the available data has limitations, primarily with respect to the consistency between actual measurements and estimated factors. For example:

- Upstream and midstream emissions of the USLNG supply chain are based on detailed data reported to the US Environmental Protection Agency (EPA) from relevant operators at the level of producing basins or plays.[21] Emissions from coal mining are estimated using emission factors and individual mine characteristics instead of actual reported measurements.
- Similarly, data on emissions factors in the midstream segments of both Pipeline Gas and Coal supply chains is primarily based on generic emission factors for infrastructure (such as pipeline, rail and/or ocean transport of fuel), rather than actual emissions measurements.

20 We assume that a new car emits 108 gCO2/km, and the average distance travelled per year is 10,300 km. See: European Environment Agency, "Average emissions from new cars and vans in Europe continue to fall, according to provisional data," press release (June 202, 2023). https://www.eea.europa.eu/en/newsroom/news/average-emissions-from-new-cars-and-vans; and Odyssee-Mure, "Sectoral Profile – Transport: Change in Distance Travelled by Car." https://www.odyssee-mure.eu/publications/efficiency-by-sector/transport/distance-travelled-by-car.html

21 The quality of this data remains the subject of some controversy at present. *See* Genevieve Plant, Genevieve, et al., Eric A. Kort, Adam R. Brandt, Yuanlei Chen, Graham Fordice, Alan M. Gorchov Negron, Stefan Schwietzke, Mackenzie Smith, Daniel Zavala-Araiza. "Inefficient and unlit natural gas flares both emit large quantities of methane,". Science , 2022; 377 (6614) (2022): 1566. DOI: 10.1126/science.abq0385

Comparison with Other Studies

There has been an increased focus on the comparison of the GHG emissions of different fuels, including USLNG, Pipeline Gas, and Coal. Recent studies conclude that, in some cases, the GHG emissions footprint of Coal supplies for power generation can be even lower than that of USLNG.[22] Our review of these studies indicates that they differ from this analysis in several respects, as summarized in Table 5.

TABLE 5: PRIMARY DIFFERENCES BETWEEN STUDIES

Areas of Difference	This Study	Other Studies
Methodology	This study employs a comprehensive, widely used methodology to separately calculate emissions intensity for each supply chain segment for actual USLNG, Pipeline Gas, and Coal trade routes in 2022.	Other studies aggregate general, theoretical emissions of natural gas, LNG, and Coal supply chains without evaluating specific regional, trade route, or temporal distinctions.
Data used	To the greatest extent possible, this study has used the most up-to-date emissions data and reported/measured emissions for each supply chain segment and delivery route. For example, we: • Used actual 2022 data on the GHG emissions of upstream natural gas production in the US, as reported to the EPA. • Analyzed the GHG emissions of USLNG shipments to specified destinations using actual 2022 data on the vessels used and their voyage distances. • Thoroughly evaluated the composition and type of 2022 Coal imports in each destination country to accurately determine the GHG emissions of Coal supplies. • Analyzed the GHG emissions of power generation in each destination country based on the actual amount of each fuel used for power generation.	Other studies rely primarily on estimated emissions factors, which are often outdated. None of the studies we reviewed used specific trade route and/or supply chain segment data for GHG emissions. For example, these studies *do not:* • Rely on reported emissions for any part of each fuels' supply chain. • Analyze the composition and type of coal supplies used in each country. • Account for actual fuel shipping and/or transportation distances. • Account for the actual heat rates of power generation segment in each country.

22 For example, *see* Gordon, Deborah, et al., "Evaluating net life-cycle greenhouse gas emissions intensities from gas and coal at varying methane leakage rates," *Environ. Res. Lett.* 18 084008 (2023); and Howarth, Robert, "The Greenhouse Gas Footprint of Liquefied Natural Gas (LNG) Exported from the United States," Cornell University (2024) and Howarth, Robert W., "The Greenhouse Gas Footprint of Liquefied Natural Gas (LNG) Exported from the United States" (January 13, 2024 version), subject to further revision before publication as a peer-reviewed article (accessed in February 2024).

GHG Emissions Management

The quality of ground-level and aerial sensors for GHG emissions measurement and monitoring is improving at an accelerated pace. Private companies, public organizations, and governmental bodies are focusing on GHG emissions measurement and monitoring as GHG mitigation is now a priority of corporate management and public policy.

Companies and organizations have also started offering CH4 emissions data obtained through satellite imaging and sophisticated data analysis and processing. Private companies currently offer satellite data on CH4 emissions at asset-specific levels (for a fee). In the near term, we expect several independent entities to publicly provide satellite data on GHG emissions of oil and gas operations at the national, regional, and even local, asset-specific levels. These developments could facilitate increasingly accurate and consistent quantification of the GHG emissions footprint of fuel production and transportation infrastructure and supply chains across regions and countries to level the playing field across jurisdictions where GHG measurement is mandatory, voluntary, or even unavailable or incomplete. As GHG mitigation commitments and policies mature worldwide, the increased use of satellite monitoring promises to facilitate the consistency of systemic analysis of GHG emissions and emissions intensity across fuel supply chains worldwide.

Further, the enhanced consistent monitoring, reporting, and verification/certification (MRV) of GHG emissions throughout the supply chain for energy imports is increasingly a central component of the value proposition for USLNG. The GHG emissions intensity of fuel supply chains is expected to impact future energy trade, taxation, pricing, and contracts. This study illustrates the value of mastering the GHG emissions footprint analysis for the supply chain of USLNG and other competing fuels into importing countries:

- Clear identification and monitoring of emissions of the USLNG supply chain may unlock long-term contracting appetites by European and Asian buyers that are increasingly concerned about the sustainability of their gas imports in an accelerating energy transition environment, especially in light of upcoming regulations on the sources of natural gas.[23]

- Access to transparent data and information on GHG emissions footprints is critical to lenders and private equity investors seeking to understand the environmental footprints of their existing portfolios, fund new investments, and adhere to environmental, social, and governance (ESG) and sustainability regulations.

- The favorable USLNG GHG emissions footprint—and rapidly improving standards for supply chain emissions measurement and monitoring—can enhance the competitive edge of USLNG against other energy sources by definitively and objectively demonstrating its lower GHG emissions intensity. Over time, this should support a price premium relative to other supplies with higher GHG emission intensities.

GHG emissions management is at the forefront of energy-sector decarbonization efforts worldwide. Continuous improvements in MRV technologies and GHG emissions data analysis are becoming a priority for governments and companies seeking to drive and implement sustainable GHG mitigation strategies. In the LNG industry, the sustained competitiveness of the fuel overall—and of specific LNG supply sources and routes—increasingly depends on the GHG emissions intensity of supply chains and supply chain economics and pricing.

23 For example, in November 2023, a provisional agreement was reached between the European Parliament and European Council reached a provisional agreement on a new EU Rregulation to reduce energy -sector methane emissions in Europe and global supply chains. *See*, European Commission, Press Release: "Commission welcomes deal on first-ever EU law to curb methane emissions in the EU and globally," press release, Brussels, (November. 2023).

APPENDIX A

DATA SOURCES

This analysis is based on the following data sources and information;

- US Environmental Protection Agency (EPA) Greenhouse Gas Reporting Program (2023).
- S&P Capital IQ.
- Kpler.
- UN Comtrade.
- U.S. Department of Energy (DOE).
- European Environment Energy.
- Energy Institute Statistical Review of World Energy (2023).
- International Gas Union.
- International Maritime Organization.
- Energy Information Administration (EIA).
- International Energy Agency (IEA) World Energy Balances (2023). All rights reserved.
- IEA Global Methane Tracker.
- Intergovernmental Panel on Climate Change (IPCC).
- Eurostat.
- Climate TRACE.
- Global Energy Monitor.
- Rosselot, Kirsten, David T. Allen, & Anthony K. Yu, "Comparing greenhouse gas impacts from domestic coal and imported natural gas electricity generation in China," *ACS Sustainable Chem.* Eng. 9:26 (2021), pp. 8759–8769.
- Roman-White, S., S. Rai, J. Littlefield, G. Cooney, & T.J. Skone, *Life Cycle Greenhouse Gas Perspective on Exporting Liquefied Natural Gas from the United States: 2019 Update,* National Energy Technology Laboratory: Pittsburgh (September 2019).
- Rosselot, Kirsten Sinclair, Paul Balcombe, Arvind P. Ravikumar, & David Thomas Allen, "Simulating the Variability of Methane and CO2 Emissions from Liquefied Natural Gas Shipping: A Time-in-Mode and Carrier Technology Approach," *ACS Sustainable Chem. Eng.* 11:43 (2023), pp. 15632–15643.
- Balcombe, Paul, Kris Anderson, Jamie Speirs, Nigel Brandon, & Adam Hawkes, "Methane and CO2 emissions from the natural gas supply chain: the importance of methane and carbon dioxide emissions," Imperial College London (2015).
- Sherwood, John, Robert Bickhart, Emily Murawski, Zemin Dhanani, Blake Lytle, Patricia Carbajales-Dale, & Michael Carbajales-Dale, "Rolling coal: The greenhouse gas emissions of coal rail transport for electricity generation," *Journal of Cleaner Production* 259 (2020), 120770, ISSN 0959-6526.

APPENDIX B

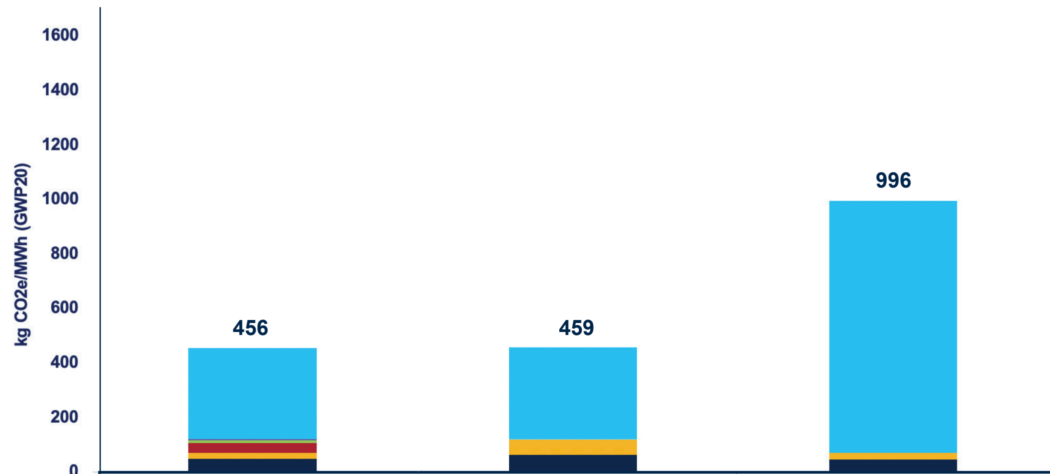
GWP100 EMISSIONS INTENSITY SUMMARY RESULTS

Another metric to quantify the CO2 equivalency between CH4 and CO2 emissions is the GWP100 (i.e., the Global Warming Potential of CH4 relative to CO2 emissions over a 100-year time horizon). This metric shows the effect of CH4 emissions 100 years after they were observed, in relation to the effect of CO2 emissions. The GWP100 of CH4 is equal to 29.8 (in comparison with GWP20 of CH4, which is equal to 82.5).[24]

Some institutions use the GWP100 as the metric of CO2 equivalency. For example, the International Group of Liquefied Natural Gas Importers (GIIGNL) requires the use of GWP100 in its Monitoring, Reporting, and Verification and GHG Neutral Framework.[25]

Using GWP100, Figure 15 and Figure 16 present the GHG emissions of USLNG, Pipeline Gas, and Coal supplies in Europe and Asia, respectively.

FIGURE 15: COMPARISON OF AVERAGE GHG EMISSIONS INTENSITY OF PRIMARY FUEL IMPORTS AND SUPPLY IN EUROPE (GWP100)

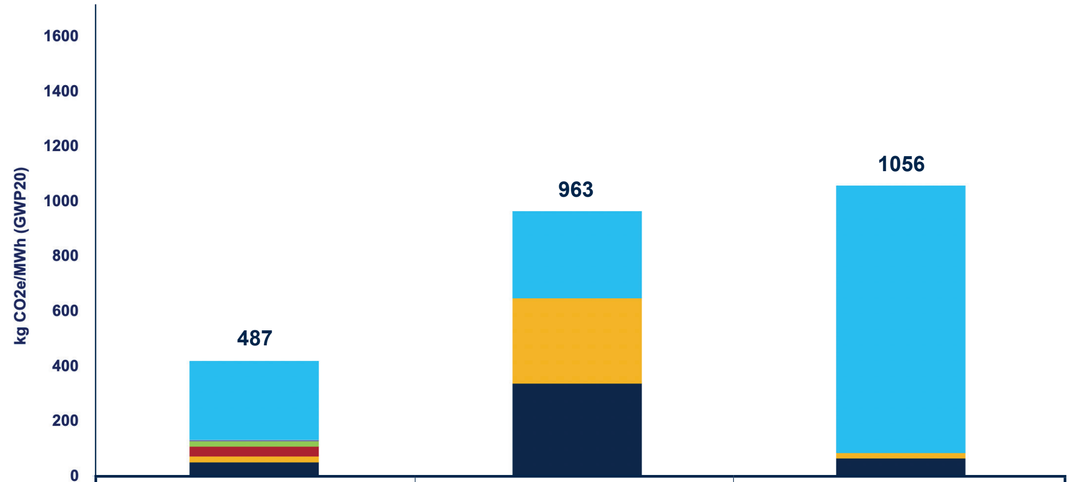


	USLNG	Pipeline Gas	Coal
Power Generation	334	338	925
Transportation to Power Plant	1	1	1
Regasification	3		
LNG Shipping	11		
Liquefaction	35		
Transport within Export Country	21	56	24
Upstream	50	64	46
Total	456	459	996

24 Forster et al. (2021), in Masson-Delmotte et al. (eds.) (2021), pp. 1017.

25 See https://giignl.org/wp-content/uploads/2021/11/MRV-and-GHG-Neutral-Framework.pdf

FIGURE 16: COMPARISON OF AVERAGE GHG EMISSIONS INTENSITY OF PRIMARY FUEL IMPORTS AND SUPPLY IN ASIA (GWP100)



	USLNG	Pipeline Gas	Coal
Power Generation	287	316	973
Transportation to Power Plant	1	0.75	0.49
Regasification	3.3		
LNG Shipping	20		
Liquefaction	35		
Transport within Export Country	21	310	19
Upstream	50	335	64
Total	487	963	1056

Table 6 demonstrates that using the GWP100 results in lower values for the total GHG emissions intensity as compared to using GWP20. This is because the impact of CH_4 emissions is approximately 33% less when considering GWP100 instead of GWP20. Using GWP100 also slightly erodes the comparison between the GHG emissions intensity of USLNG and Coal across their full supply chains.

TABLE 6: GHG EMISSIONS INTENSITY TO EUROPE AND ASIA USING GWP20 V GWP100

Total GHG Emissions Intensity (kgCO2e/MWh)	Europe		Asia	
	GWP20	GWP100	GWP20	GWP100
USLNG	507	456	543	487
Pipeline Gas	552	459	1,462	963
Coal	1,077	996	1,168	1,156

APPENDIX C

INDIVIDUAL COUNTRY RESULTS (kg CO2e / MWh, GWP 20)

In this section, we present for each destination country the GHG emissions intensity of each supply chain segment and each Primary Fuel, measured in kgCO2e/MWh at GWP20.

France

FIGURE 17: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG AND MAIN PIPELINE IMPORTS TO FRANCE

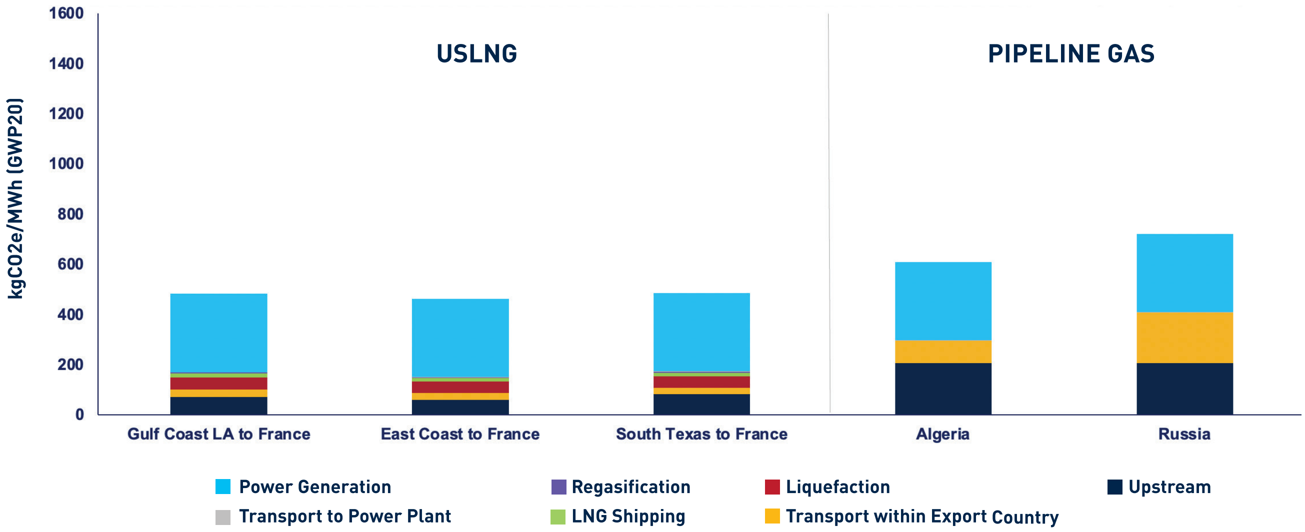
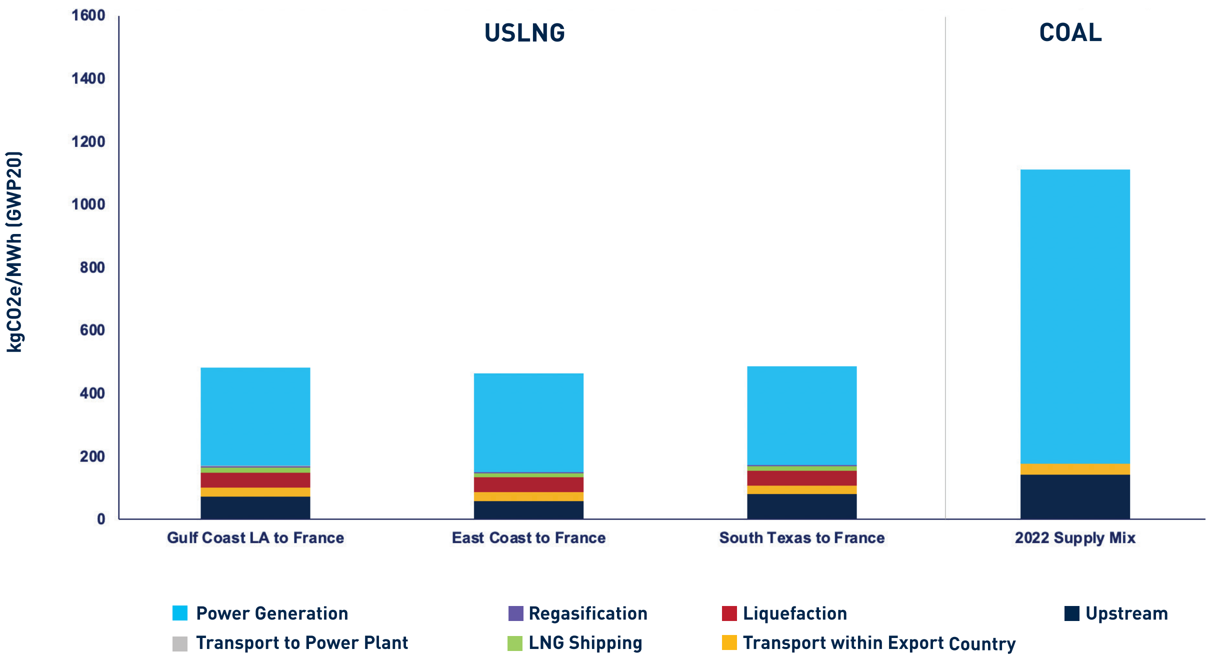


FIGURE 18: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG IMPORTS AND COAL SUPPLIES TO FRANCE



Germany

FIGURE 19: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG AND MAIN PIPELINE IMPORTS TO GERMANY

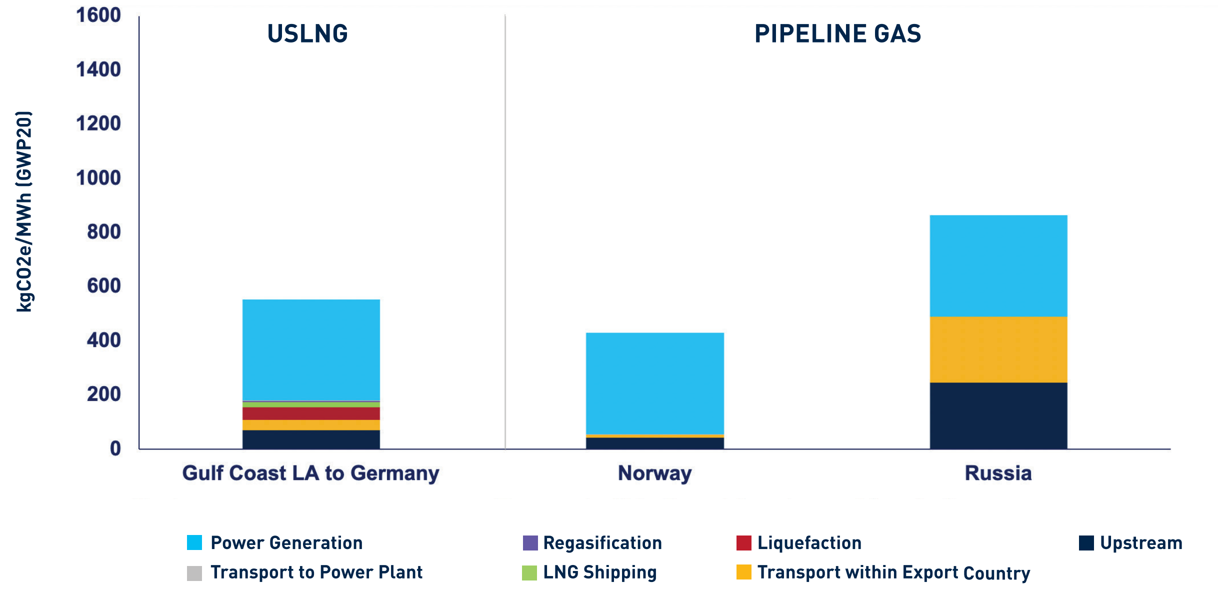
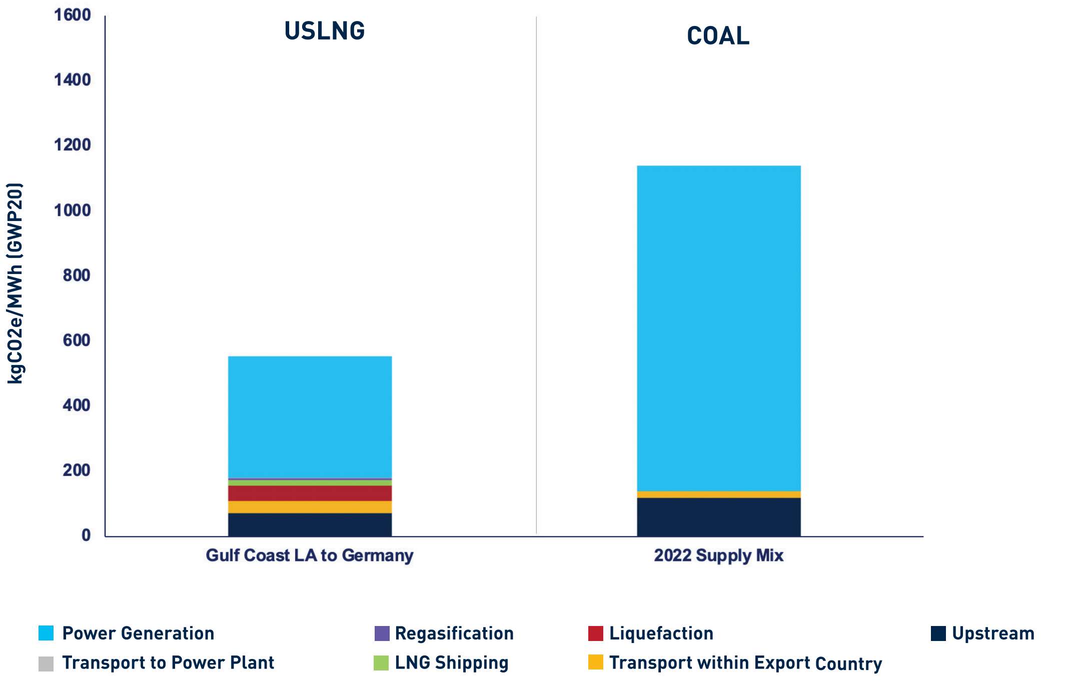


FIGURE 20: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG IMPORTS AND COAL SUPPLIES TO GERMANY



Italy

FIGURE 21: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG AND MAIN PIPELINE IMPORTS TO ITALY

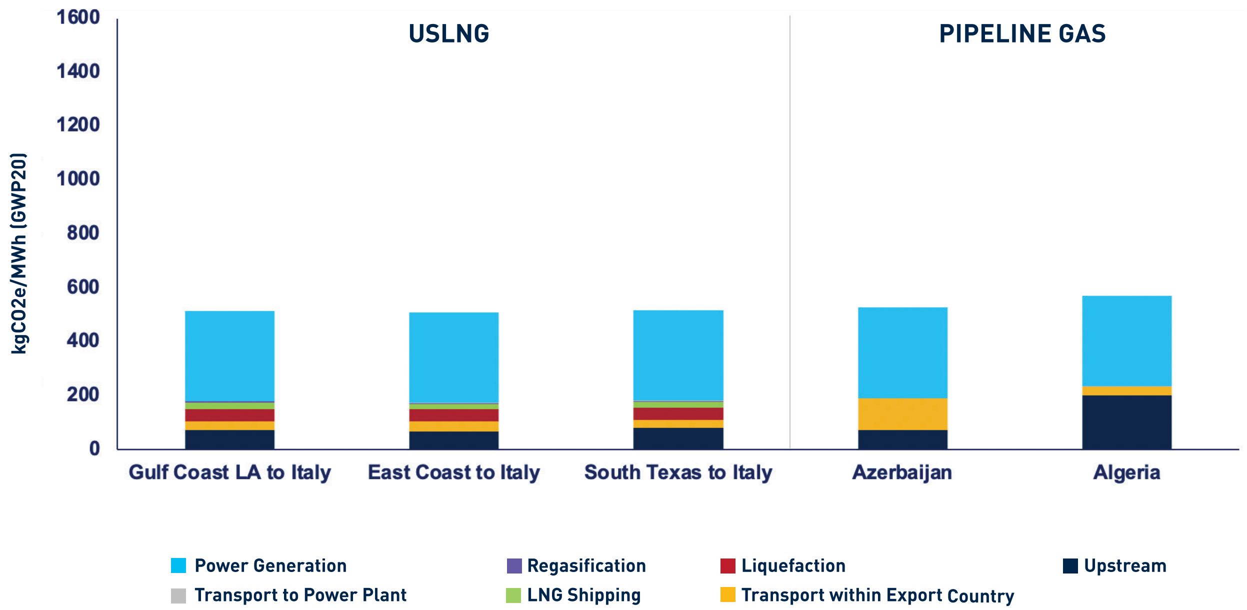
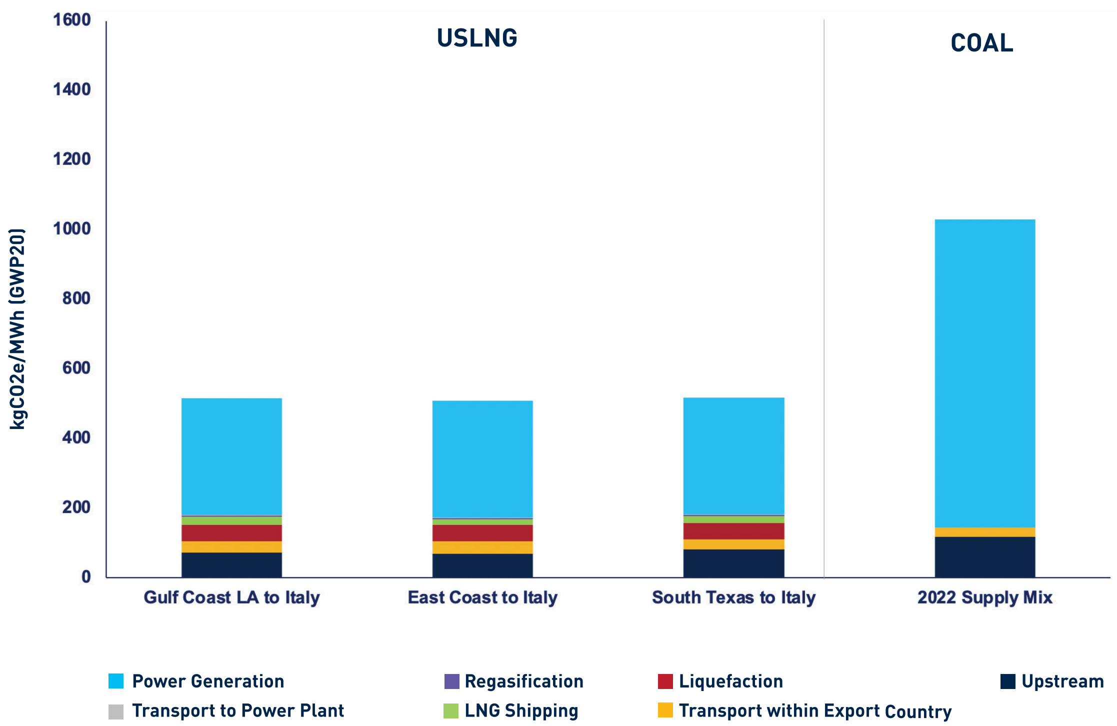


FIGURE 22: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG IMPORTS AND COAL SUPPLIES TO ITALY



The Netherlands

FIGURE 23: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG AND MAIN PIPELINE IMPORTS TO THE NETHERLANDS

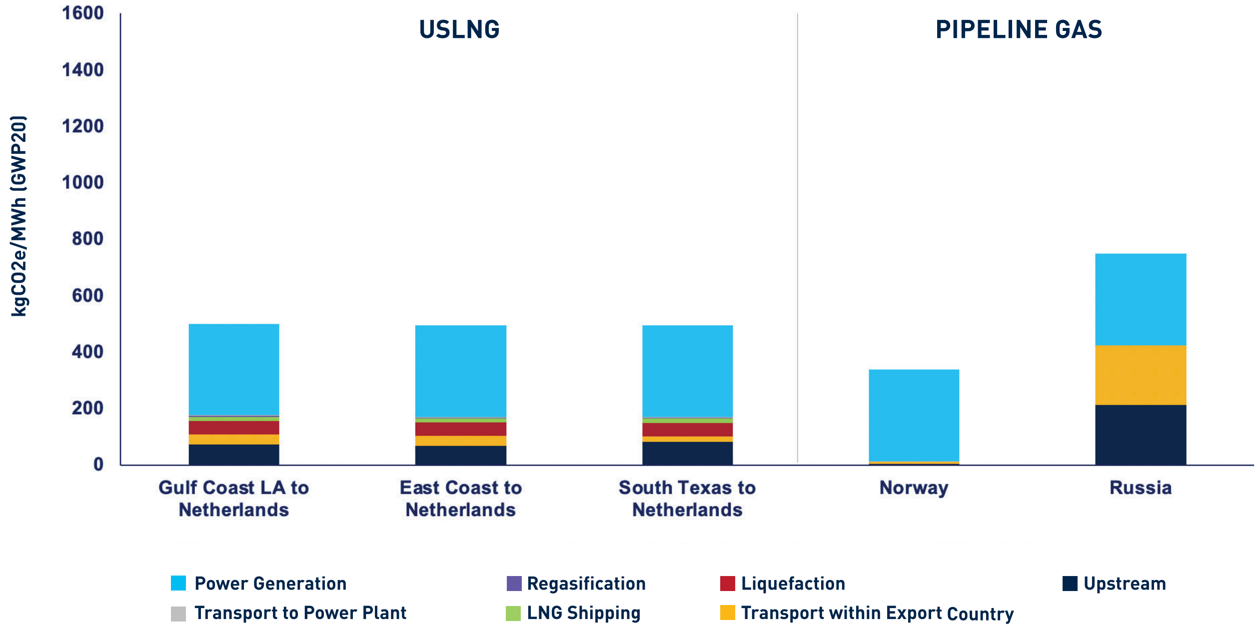
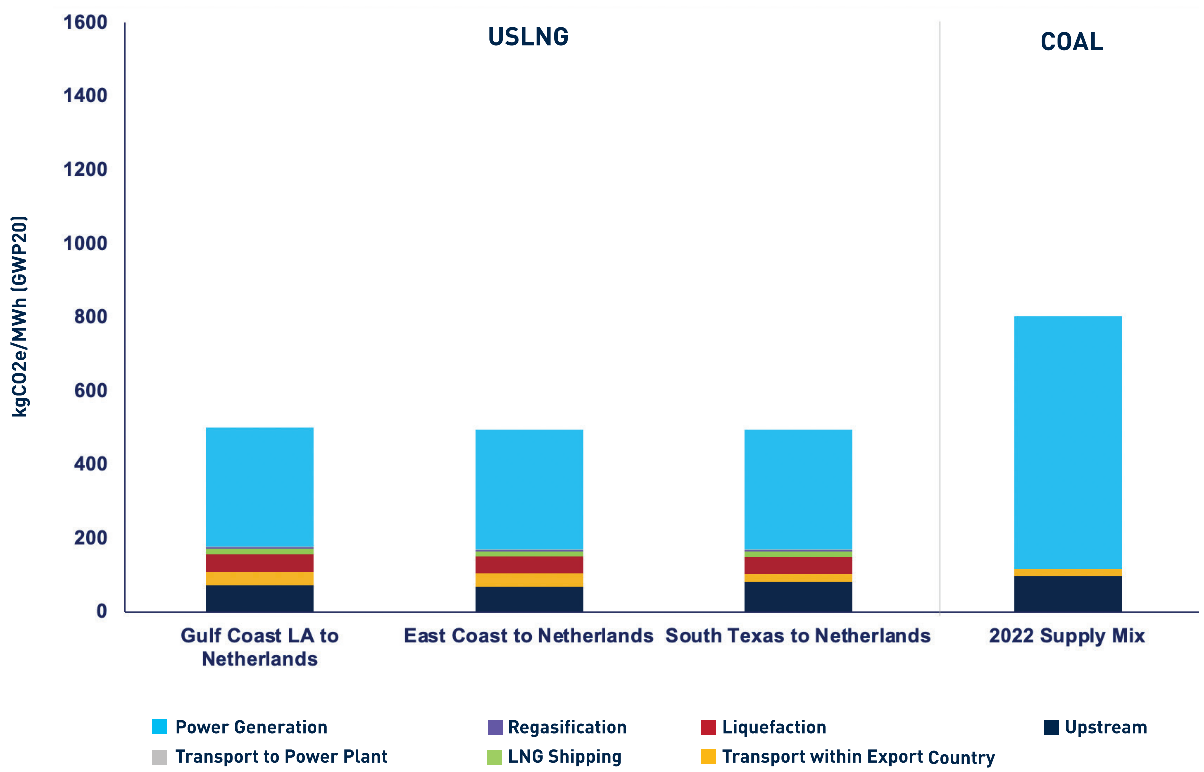


FIGURE 24: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG IMPORTS AND COAL SUPPLIES TO THE NETHERLANDS



Poland

FIGURE 25: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG AND MAIN PIPELINE IMPORTS TO POLAND

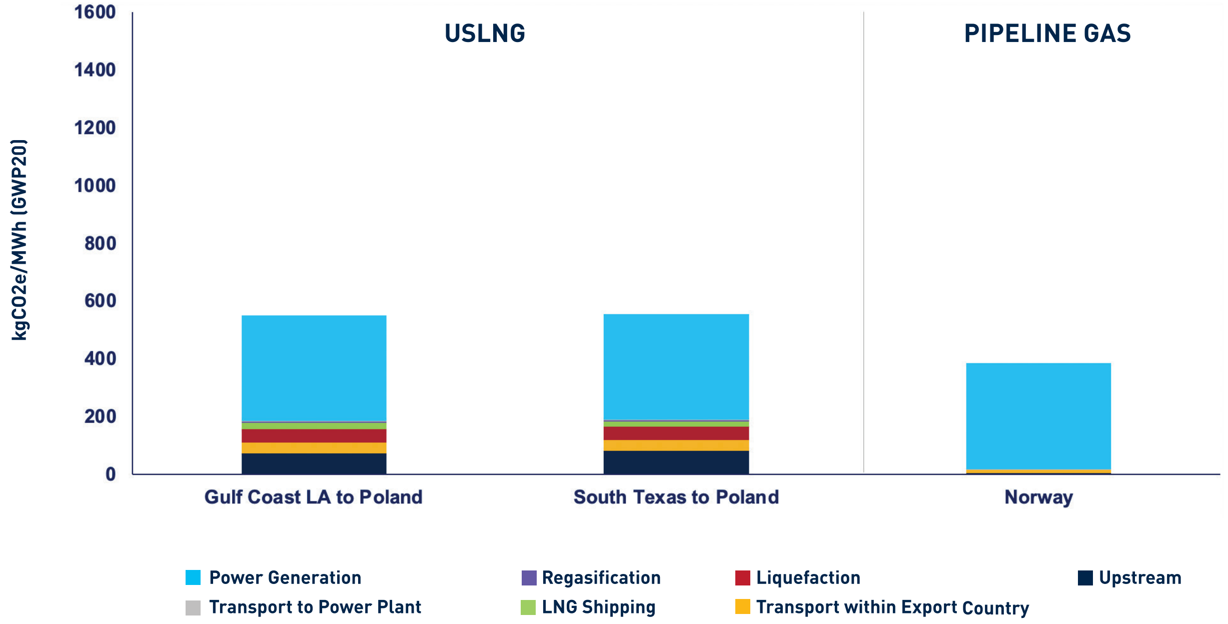
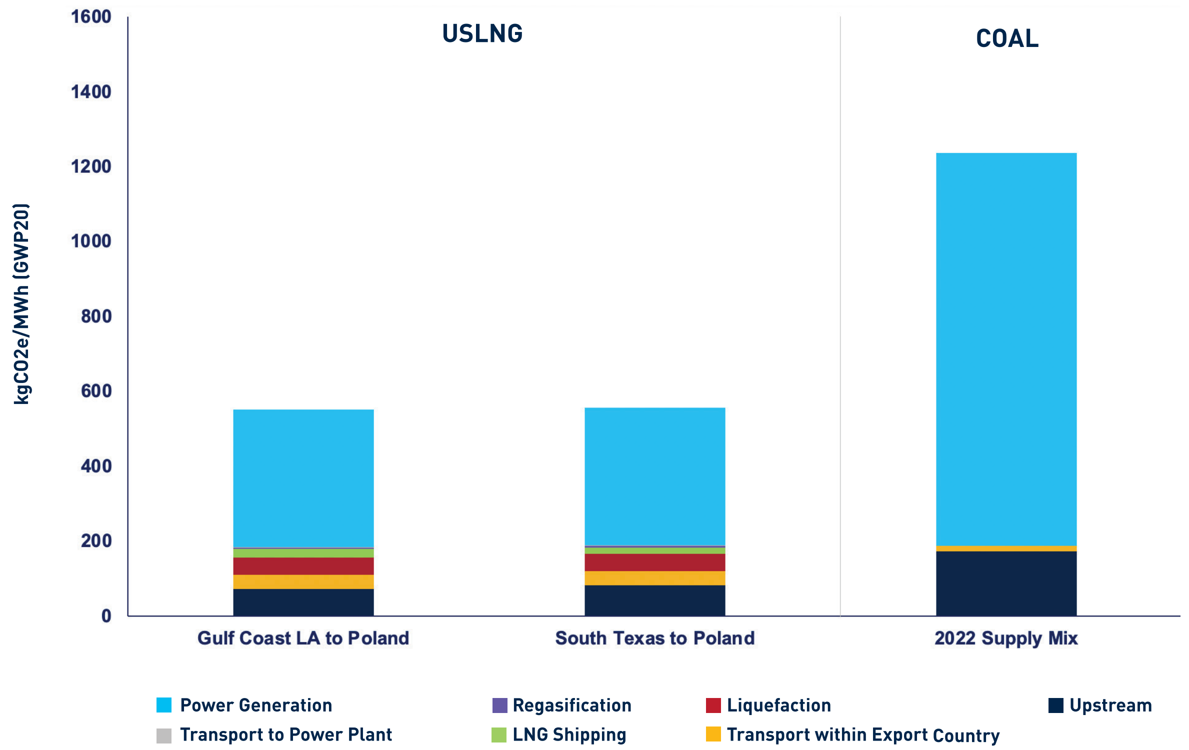


FIGURE 26: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG IMPORTS AND COAL SUPPLIES TO POLAND



Spain

FIGURE 27: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG AND MAIN PIPELINE IMPORTS TO SPAIN

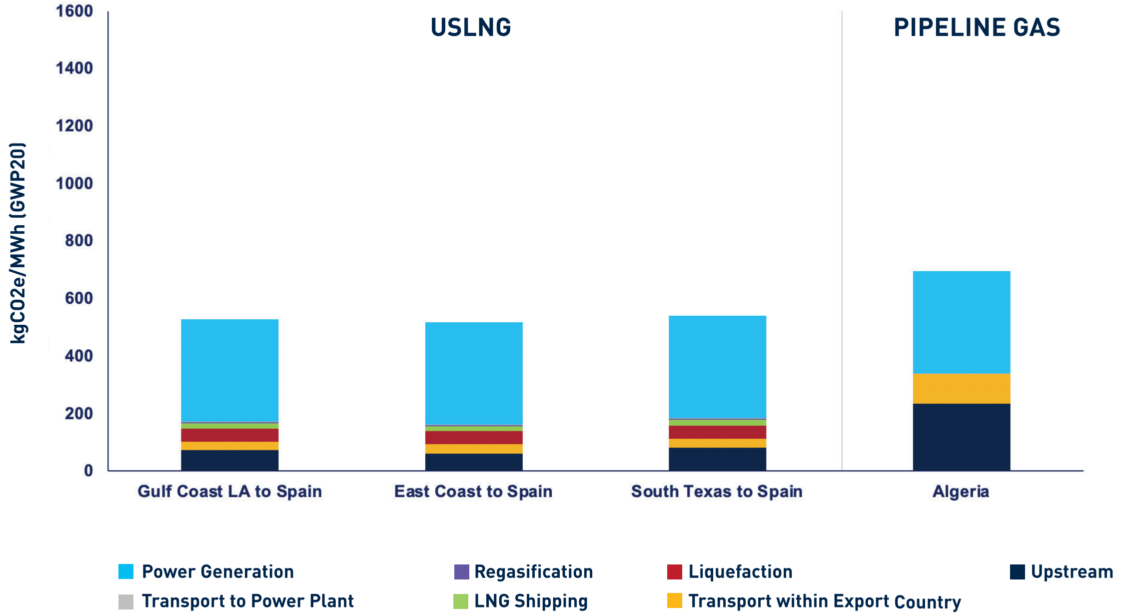
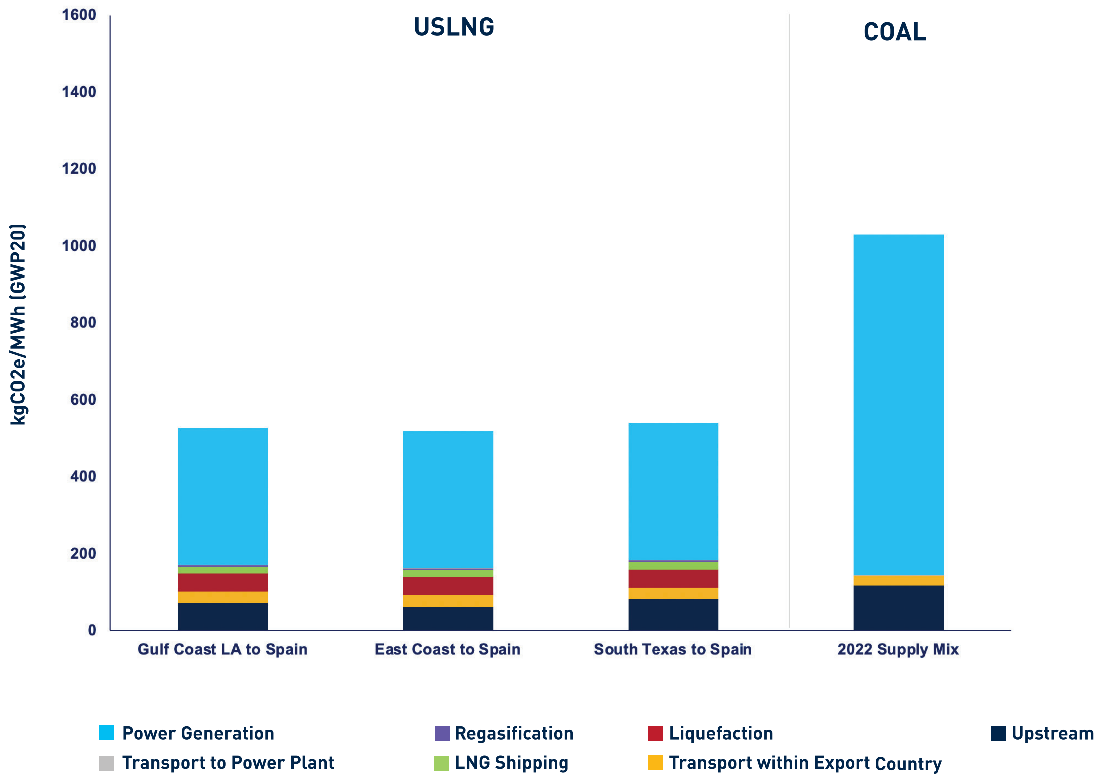


FIGURE 28: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG IMPORTS AND COAL SUPPLIES TO SPAIN



Türkiye

FIGURE 29: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG AND MAIN PIPELINE IMPORTS TO TÜRKIYE

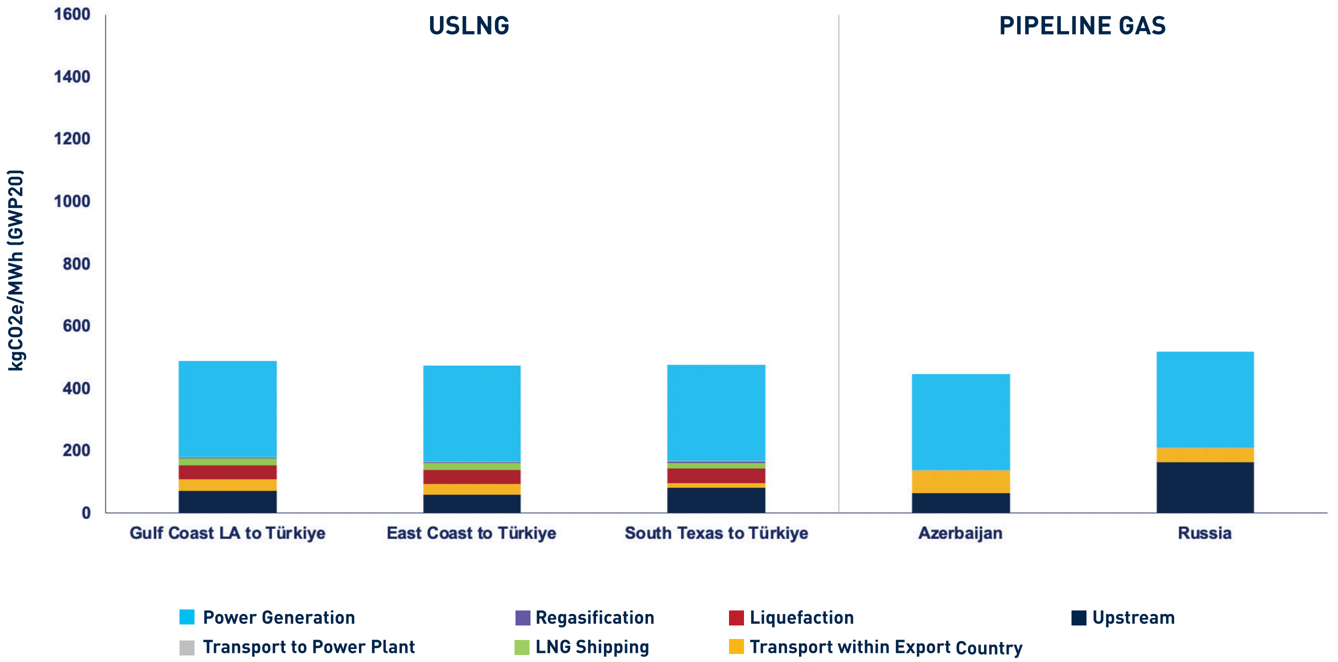
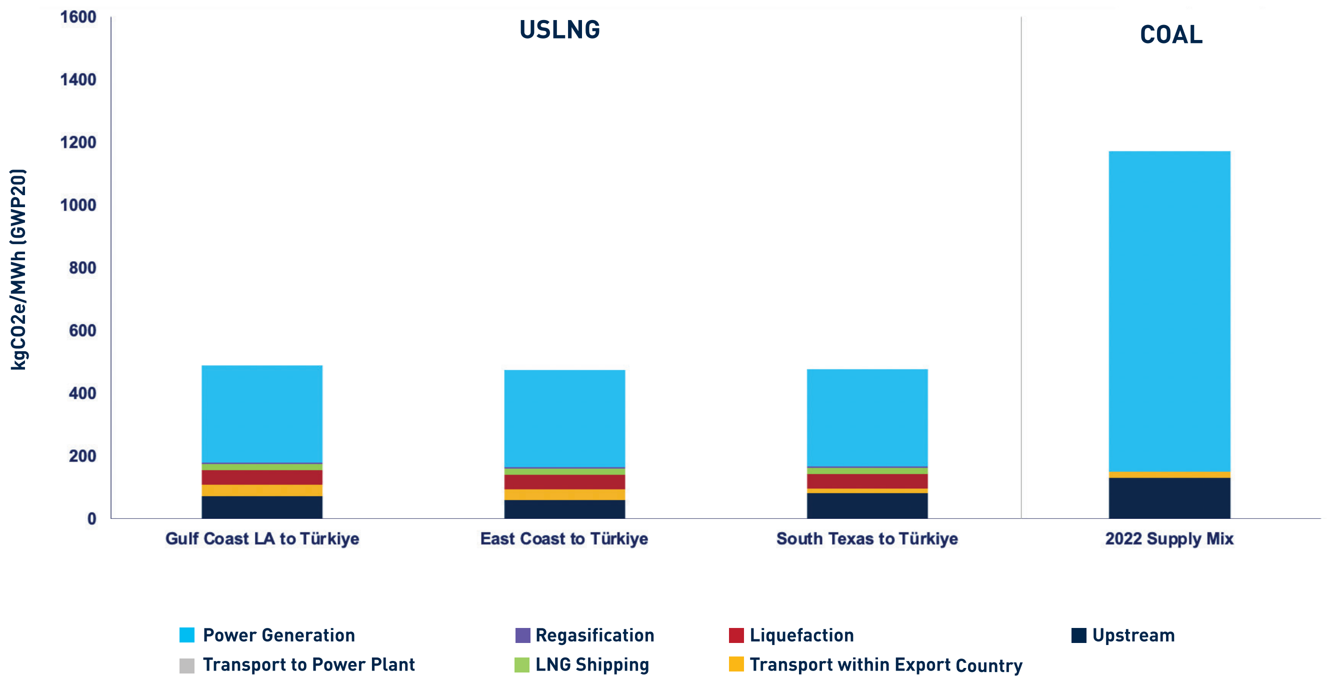


FIGURE 30: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG IMPORTS AND COAL SUPPLIES TO TÜRKIYE



United Kingdom

FIGURE 31: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG AND MAIN PIPELINE IMPORTS TO THE UNITED KINGDOM

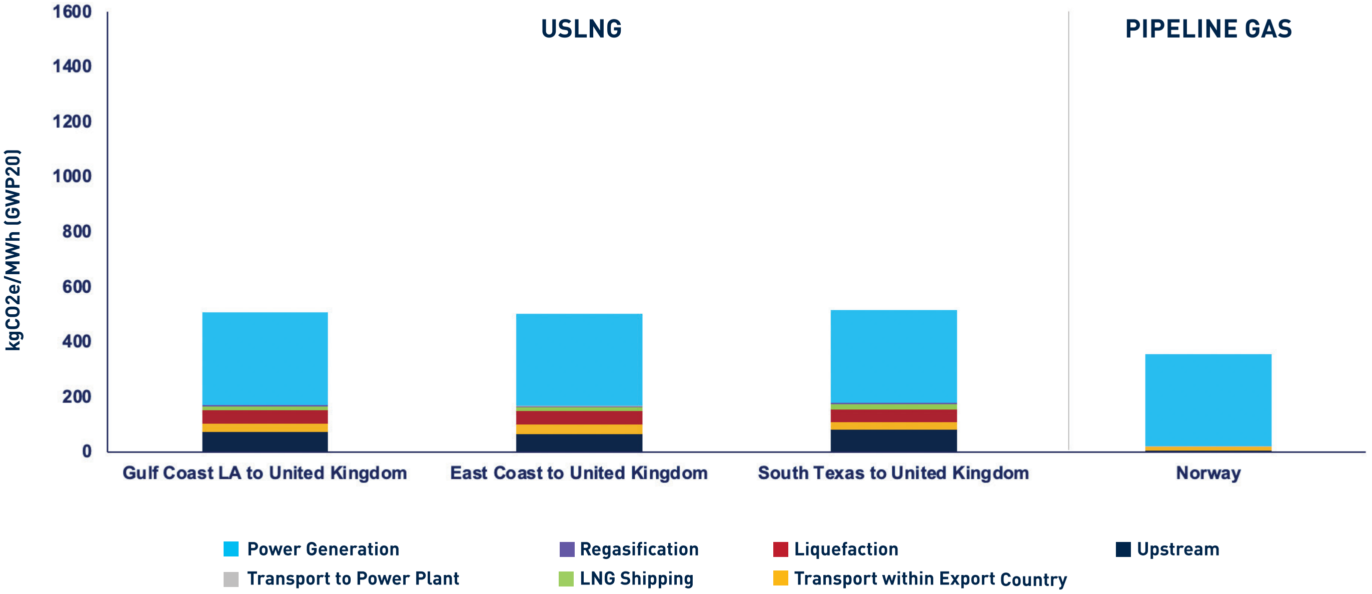
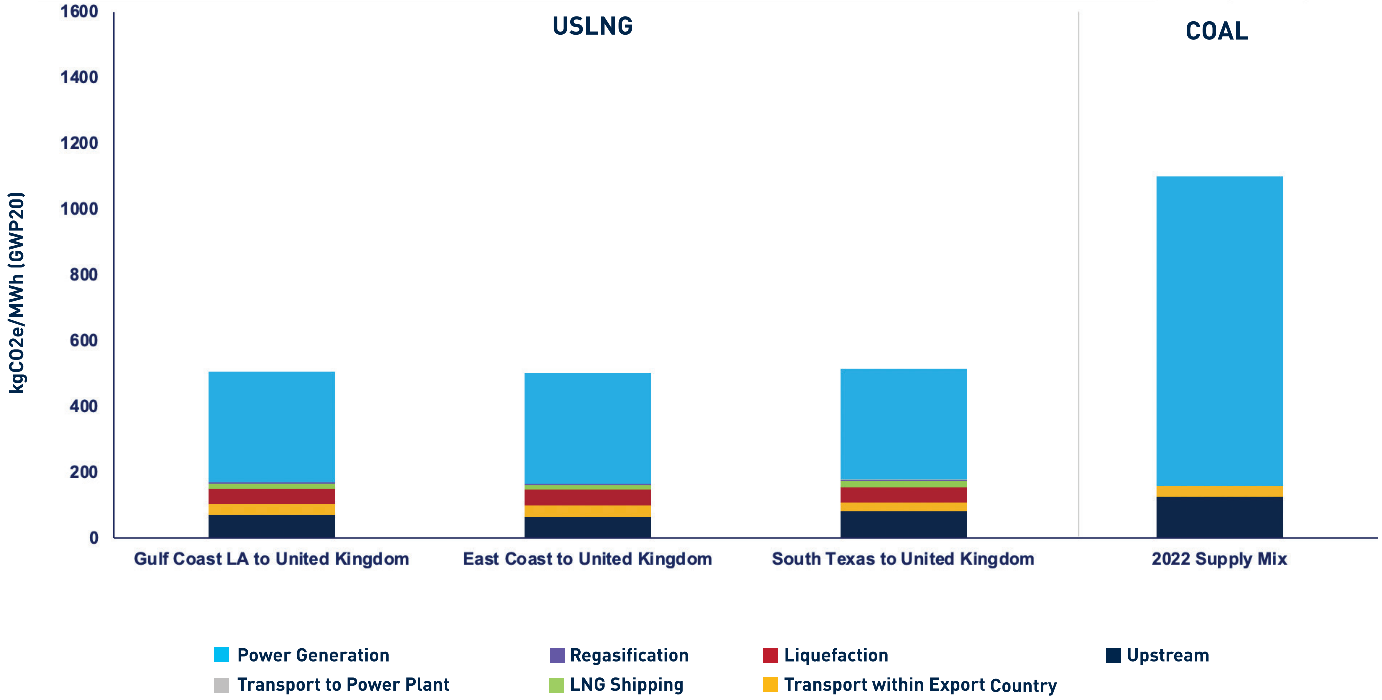


FIGURE 32: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG IMPORTS AND COAL SUPPLIES TO THE UNITED KINGDOM



China

FIGURE 33: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG AND MAIN PIPELINE IMPORTS TO CHINA

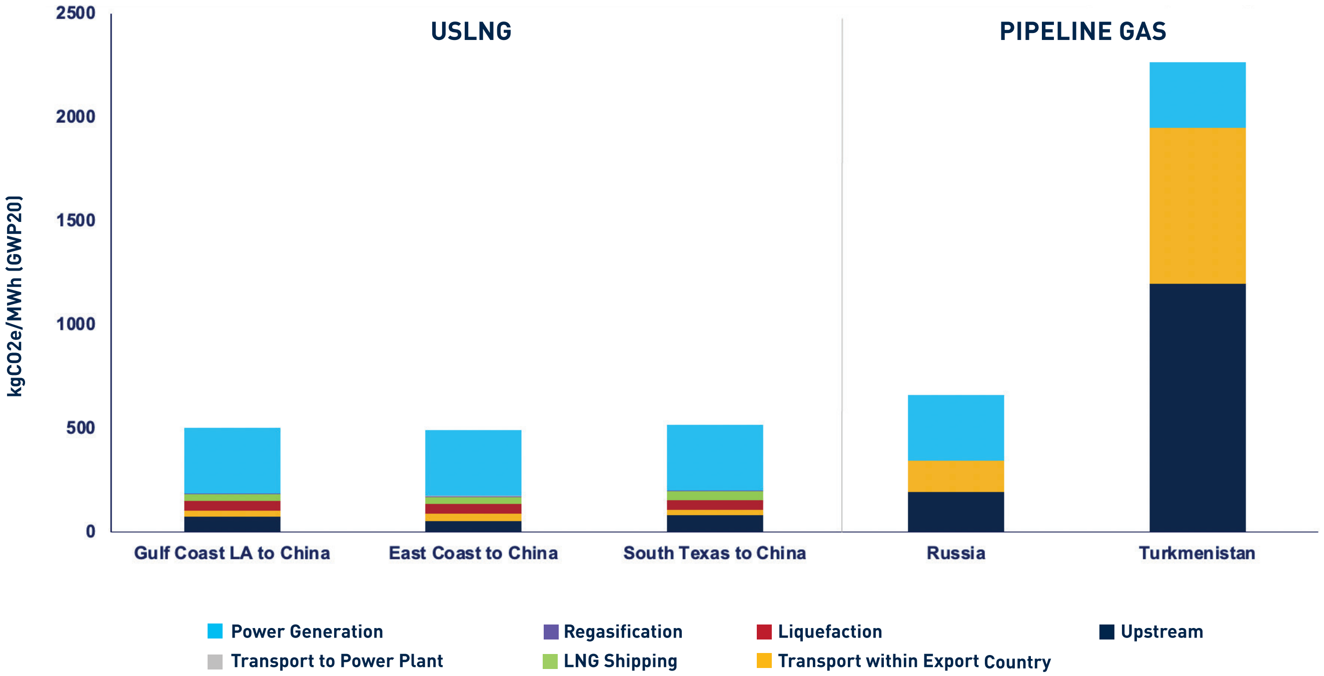
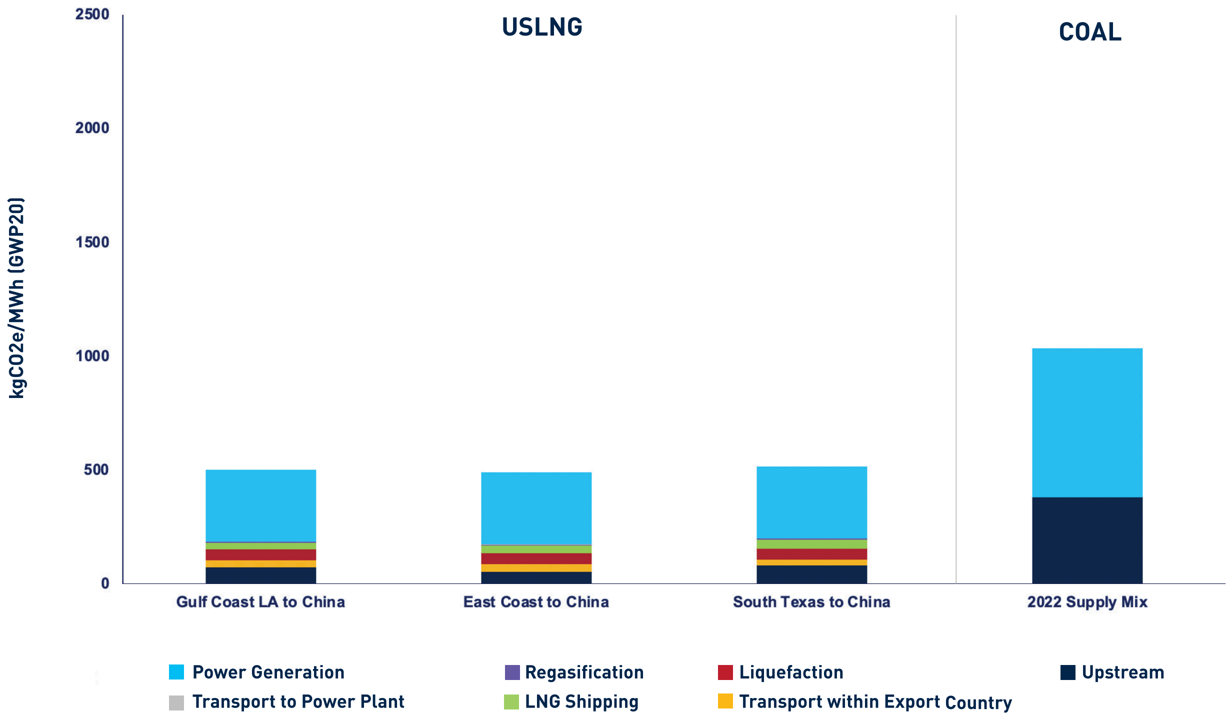
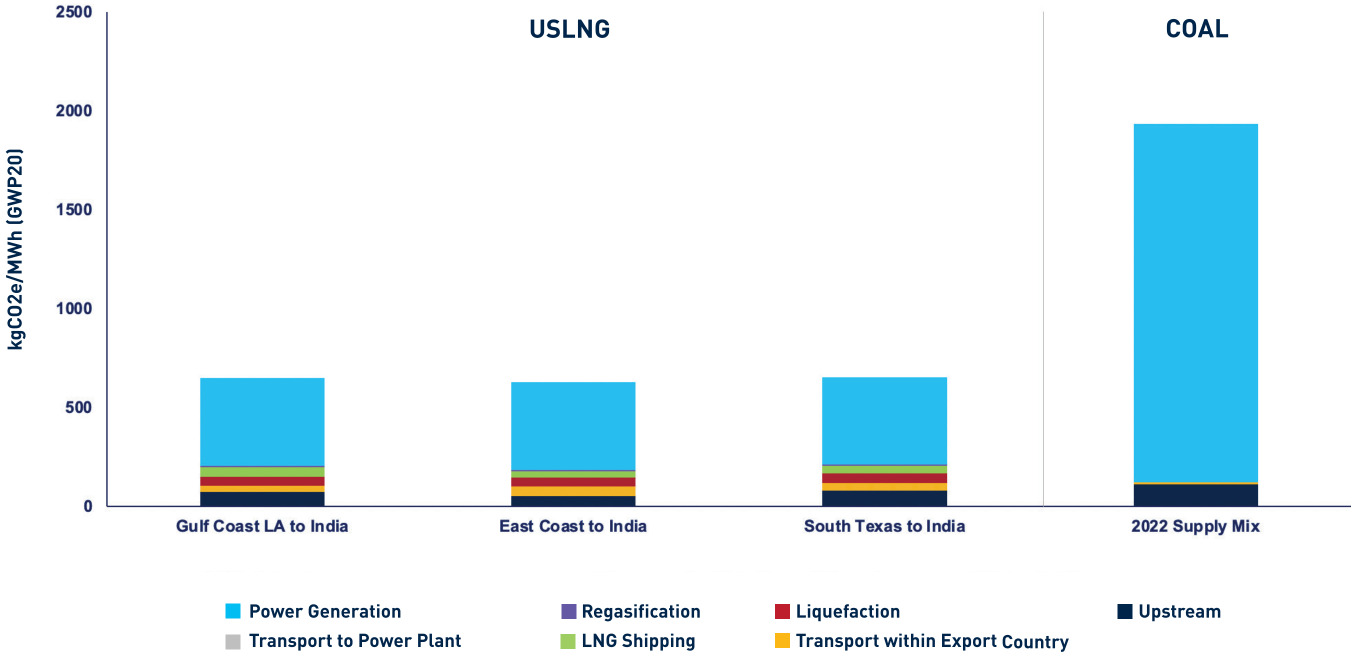


FIGURE 34: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG IMPORTS AND COAL SUPPLIES TO CHINA



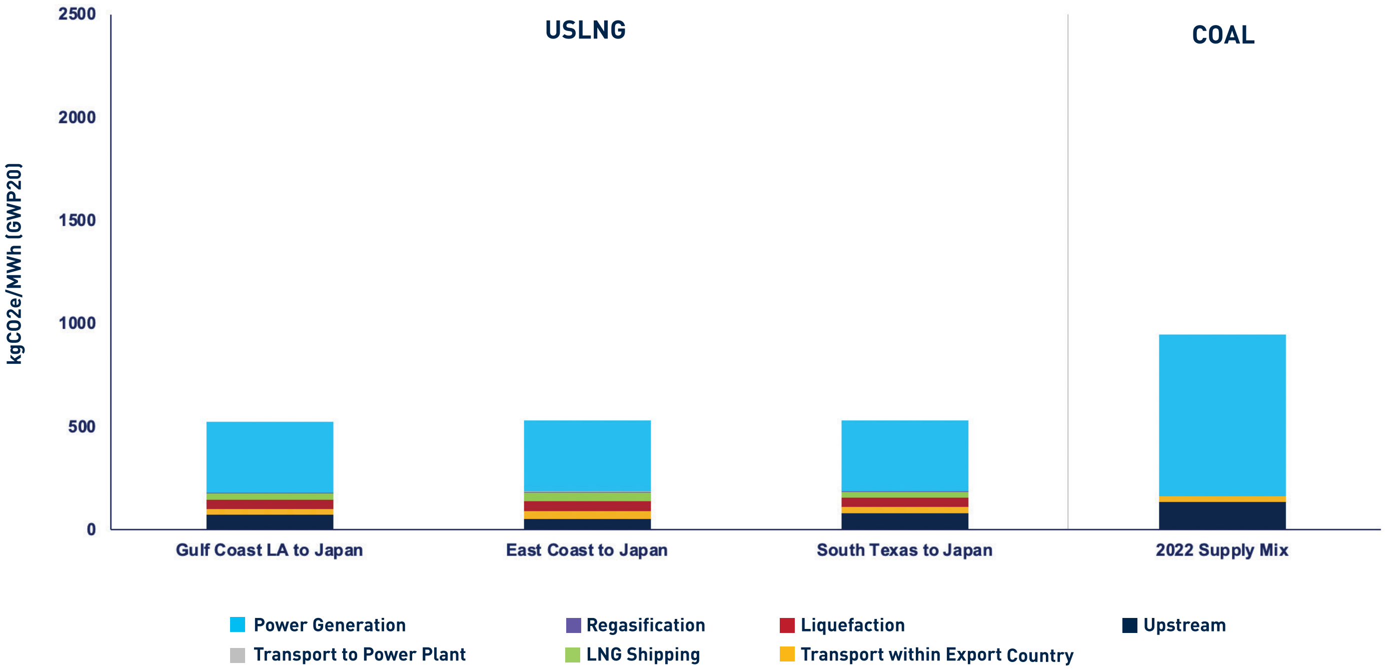
India

FIGURE 35: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG IMPORTS AND COAL SUPPLIES TO INDIA



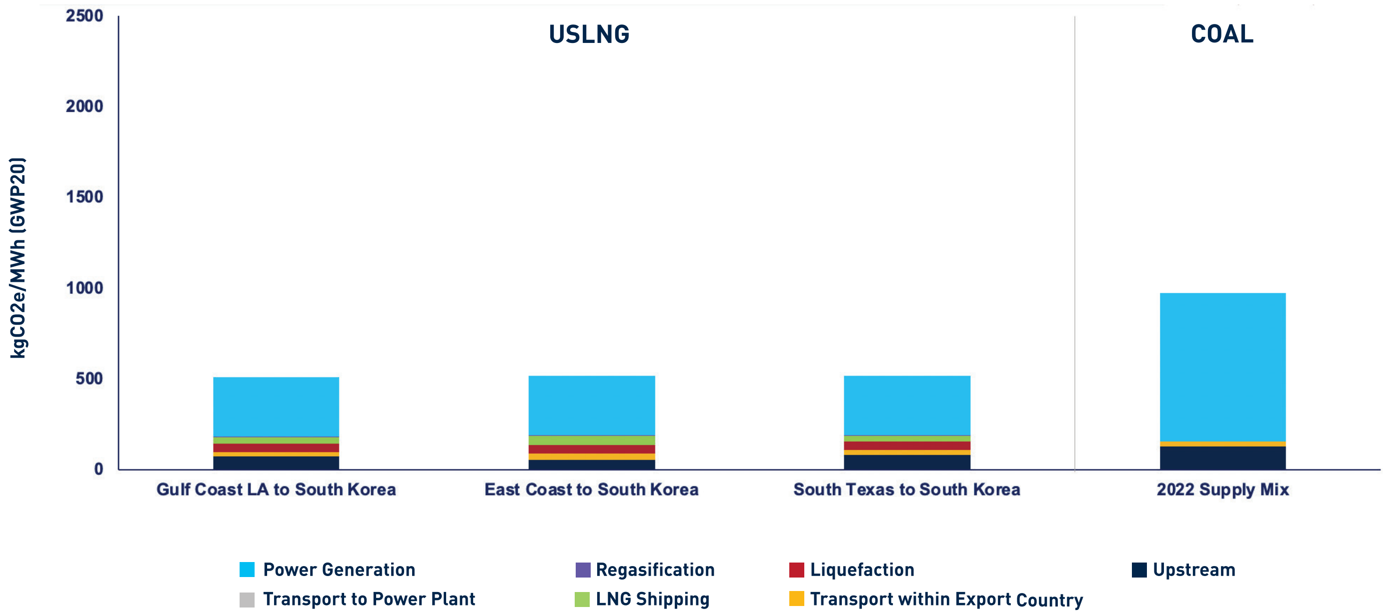
Japan

FIGURE 36: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG IMPORTS AND COAL SUPPLIES TO JAPAN



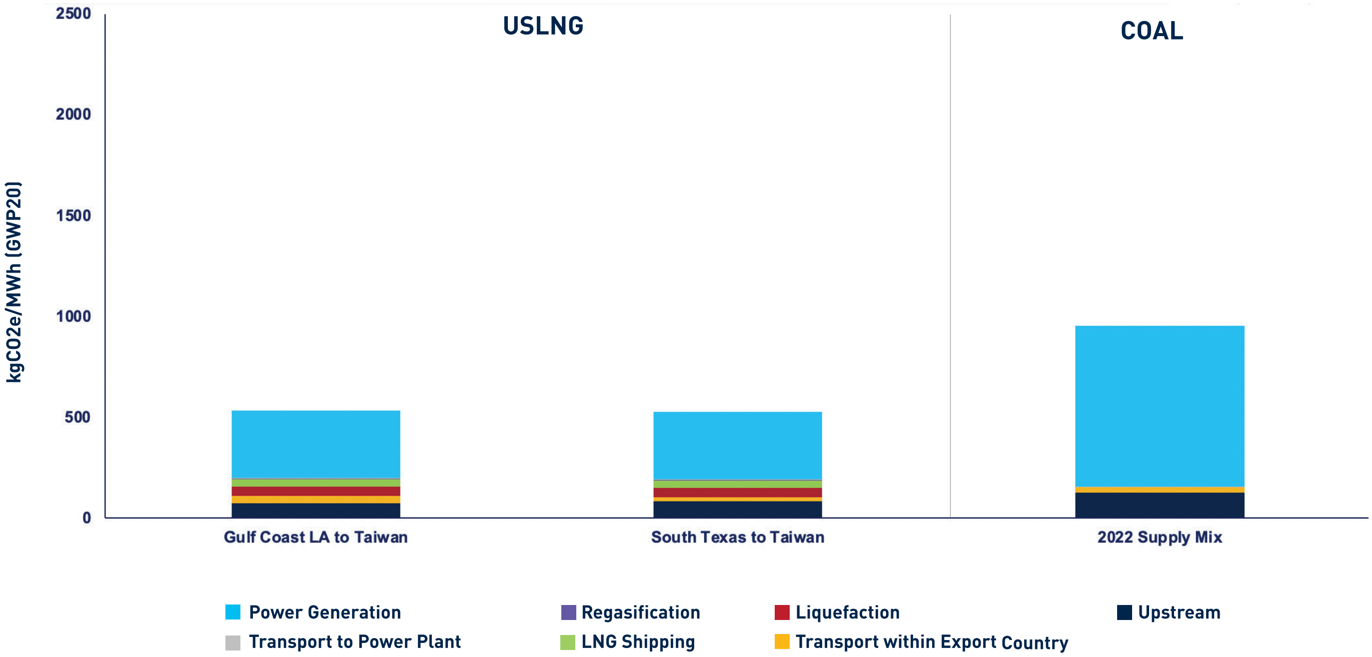
South Korea

FIGURE 37: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG IMPORTS AND COAL SUPPLIES TO SOUTH KOREA



Taiwan

FIGURE 38: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG IMPORTS AND COAL SUPPLIES TO TAIWAN



APPENDIX D

INDIVIDUAL COUNTRY RESULTS (kg CO2e / MMBtu, GWP 20)

In this section, we present for each destination country, the GHG emissions intensity of each supply chain segment and each Primary Fuel, measured in kgCO2e/MMBtu at GWP20.

France

FIGURE 39: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG AND MAIN PIPELINE IMPORTS TO FRANCE

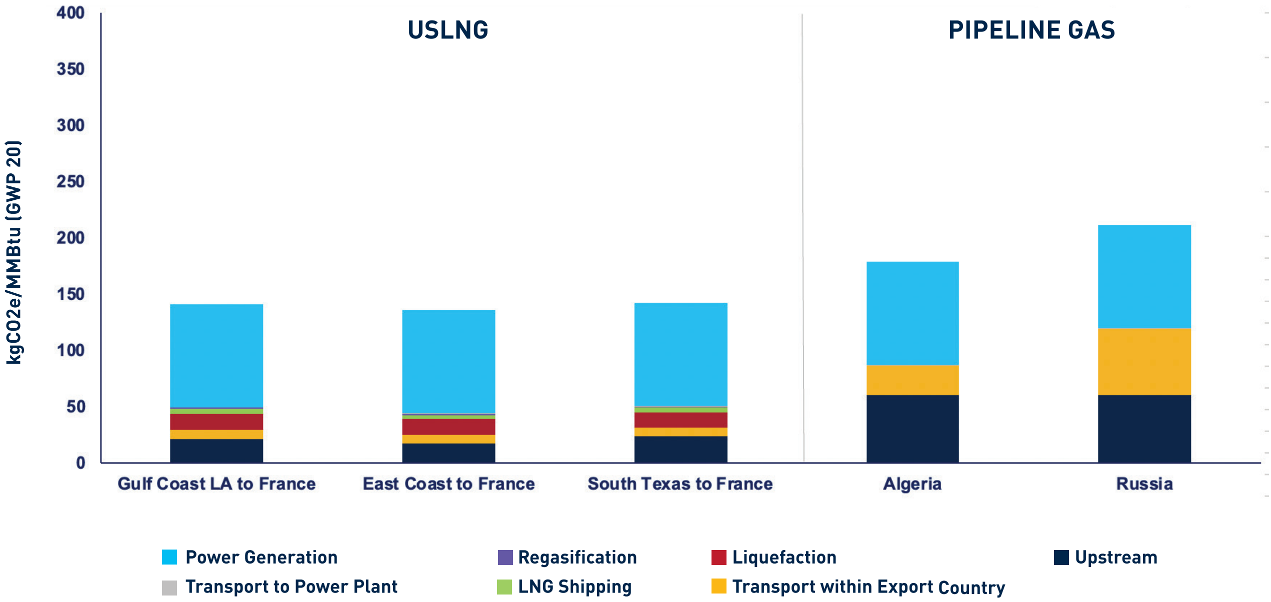
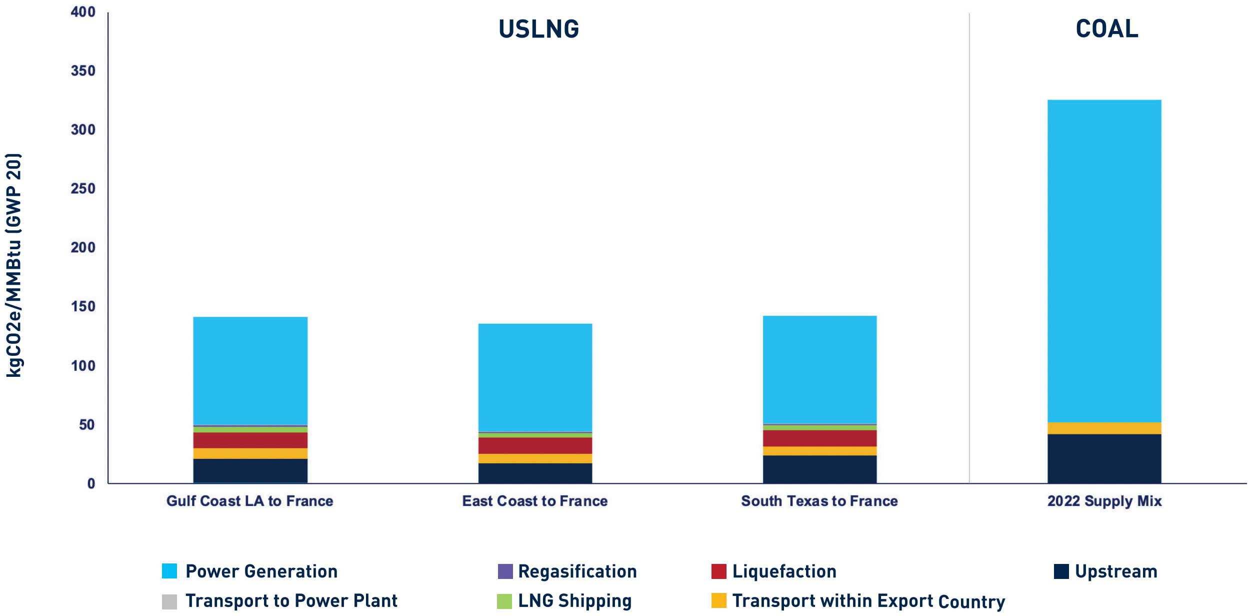


FIGURE 40: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG IMPORTS AND COAL SUPPLIES TO FRANCE



Germany

FIGURE 41: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG AND MAIN PIPELINE IMPORTS TO GERMANY

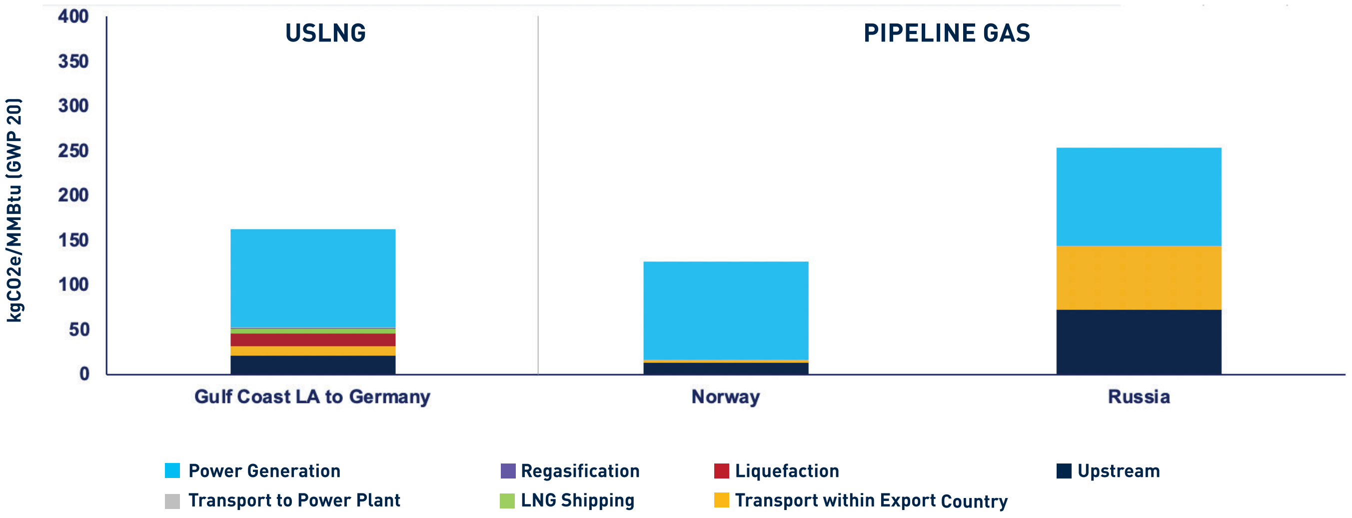
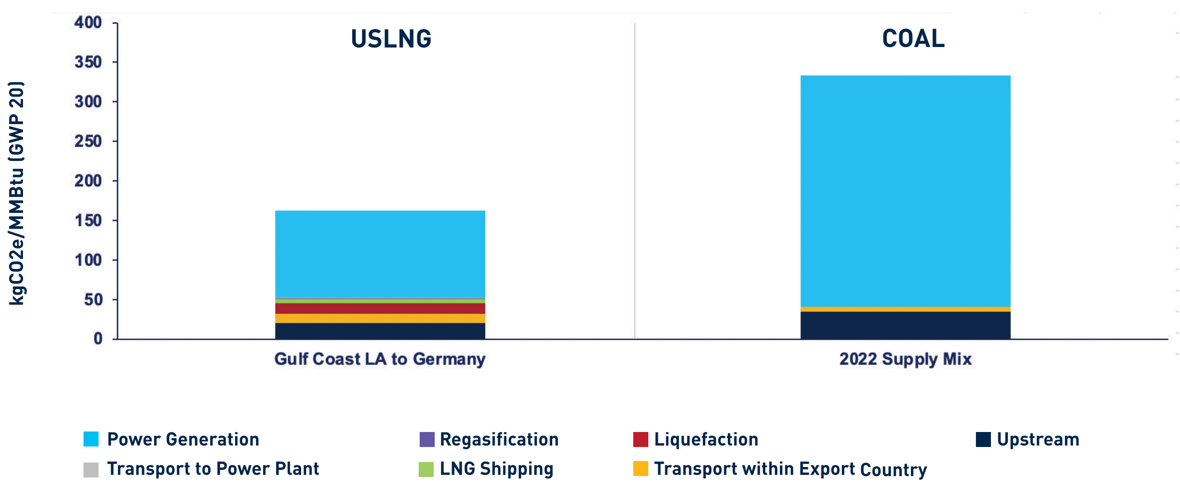


FIGURE 42: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG IMPORTS AND COAL SUPPLIES TO GERMANY



Italy

FIGURE 43: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG AND MAIN PIPELINE IMPORTS TO ITALY

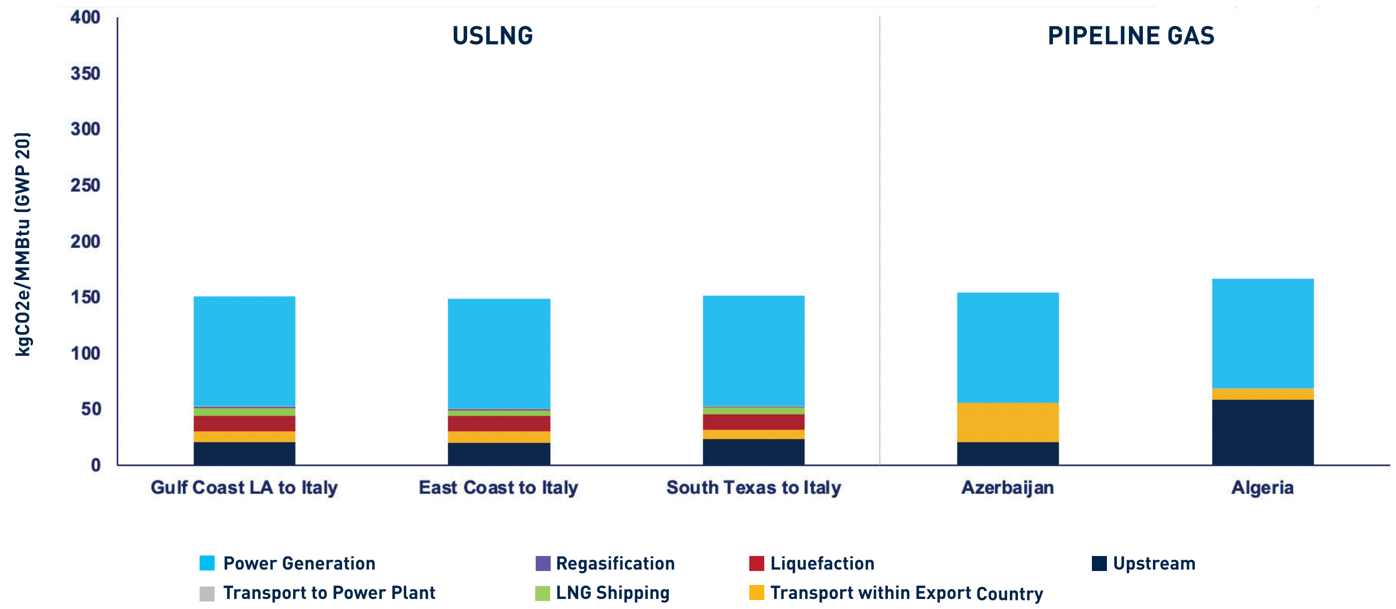
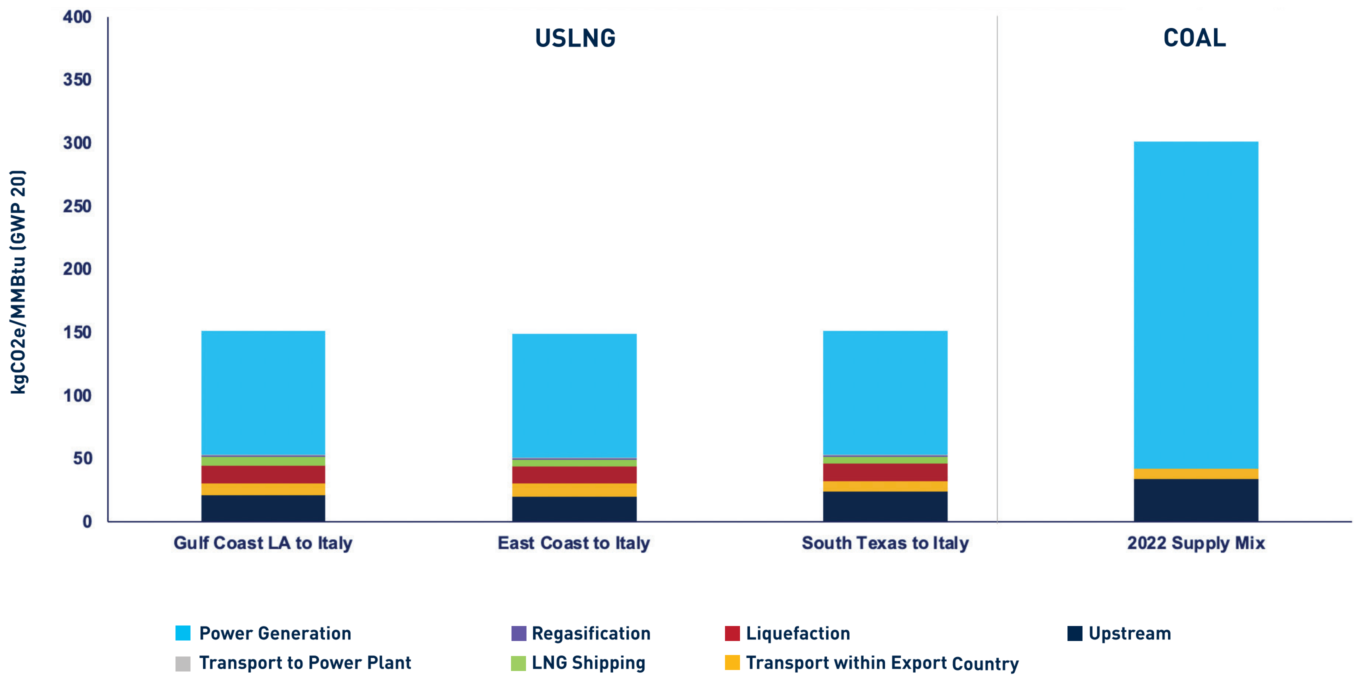


FIGURE 44: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG IMPORTS AND COAL SUPPLIES TO ITALY



The Netherlands

FIGURE 45: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG AND MAIN PIPELINE IMPORTS TO THE NETHERLANDS

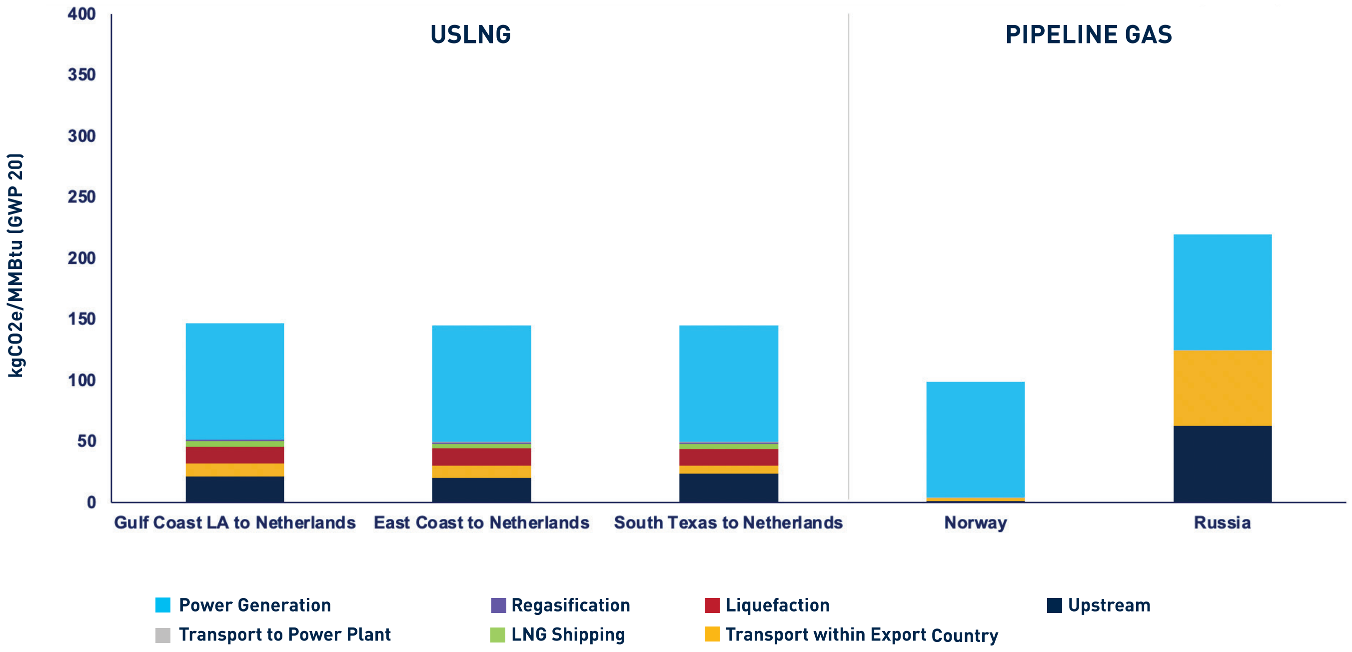
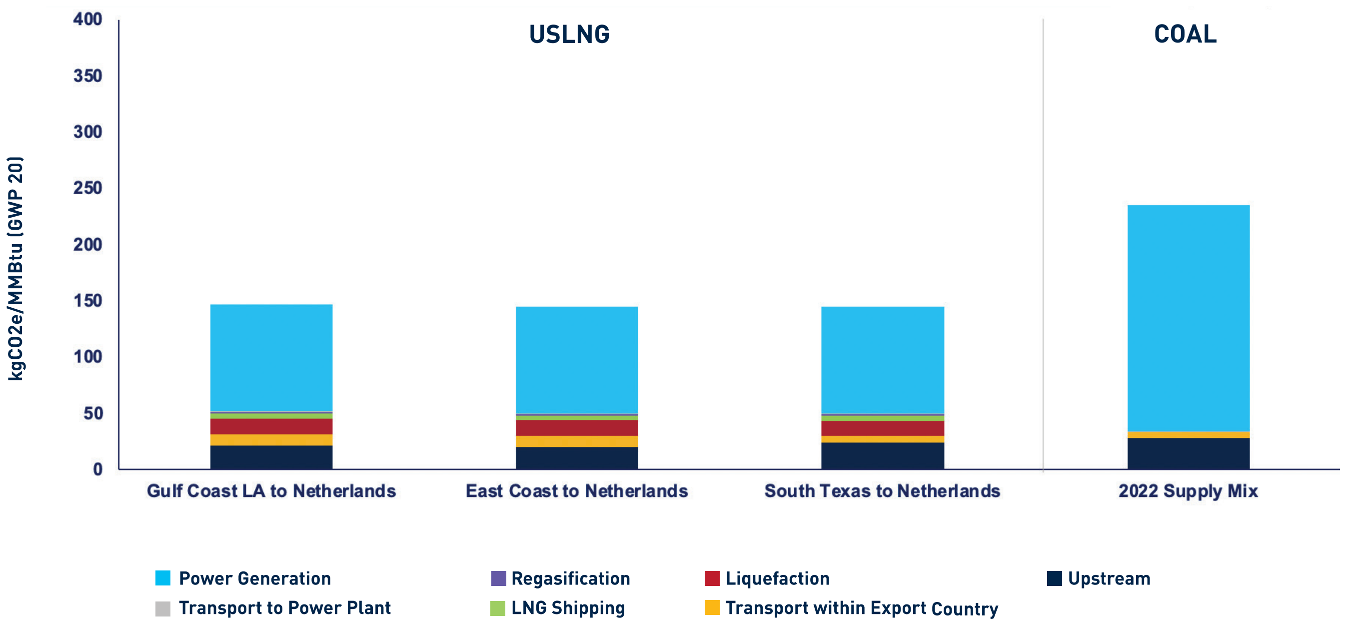


FIGURE 46: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG IMPORTS AND COAL SUPPLIES TO THE NETHERLANDS



Poland

FIGURE 47: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG AND MAIN PIPELINE IMPORTS TO POLAND

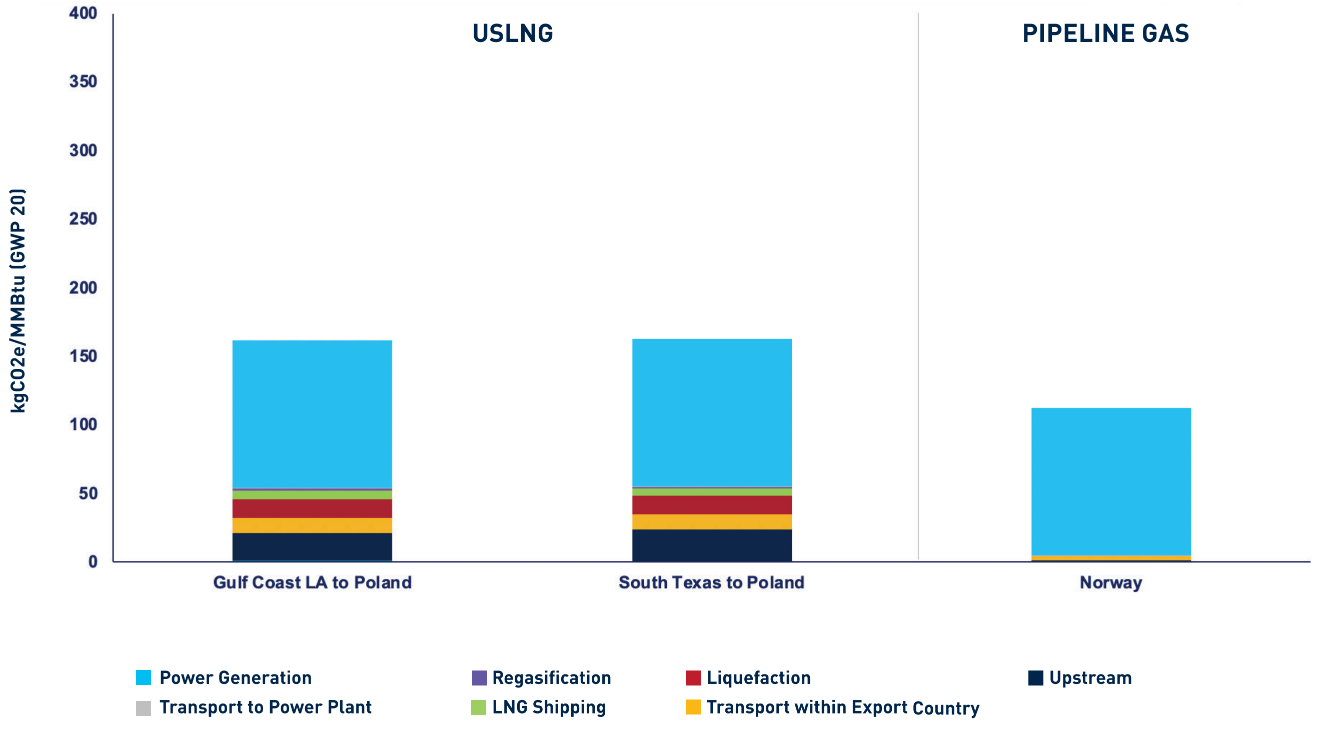
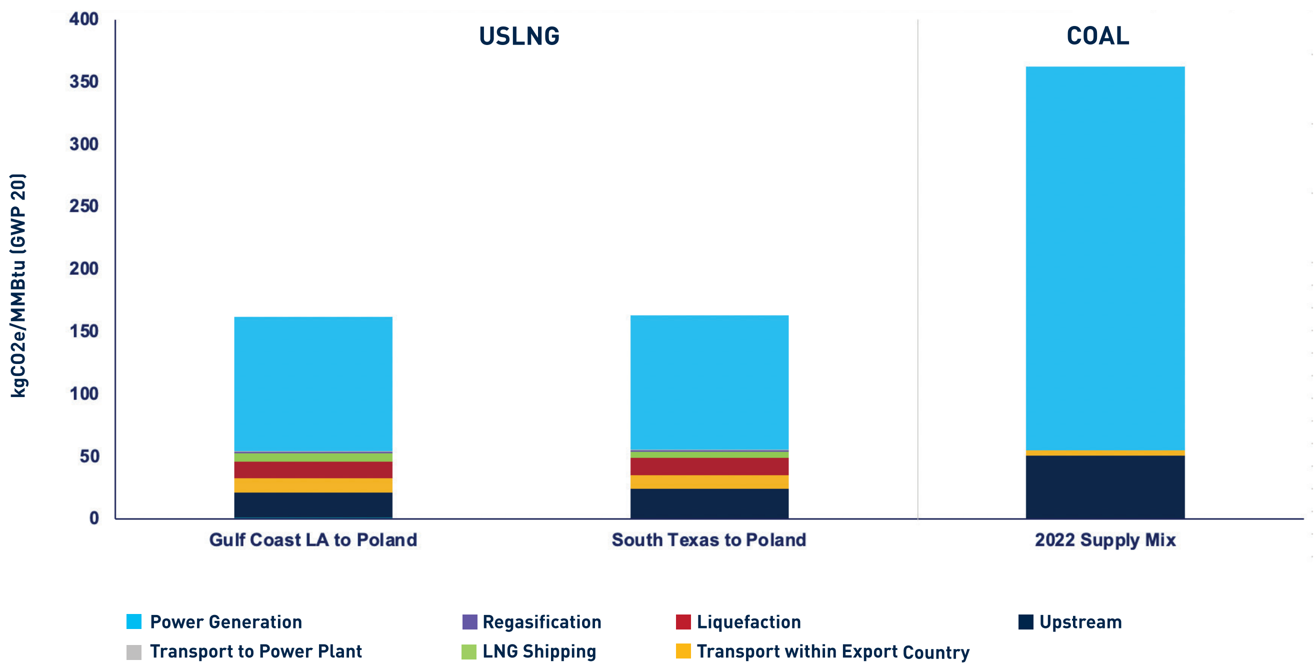


FIGURE 48: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG IMPORTS AND COAL SUPPLIES TO POLAND



Spain

FIGURE 49: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG AND MAIN PIPELINE IMPORTS TO SPAIN

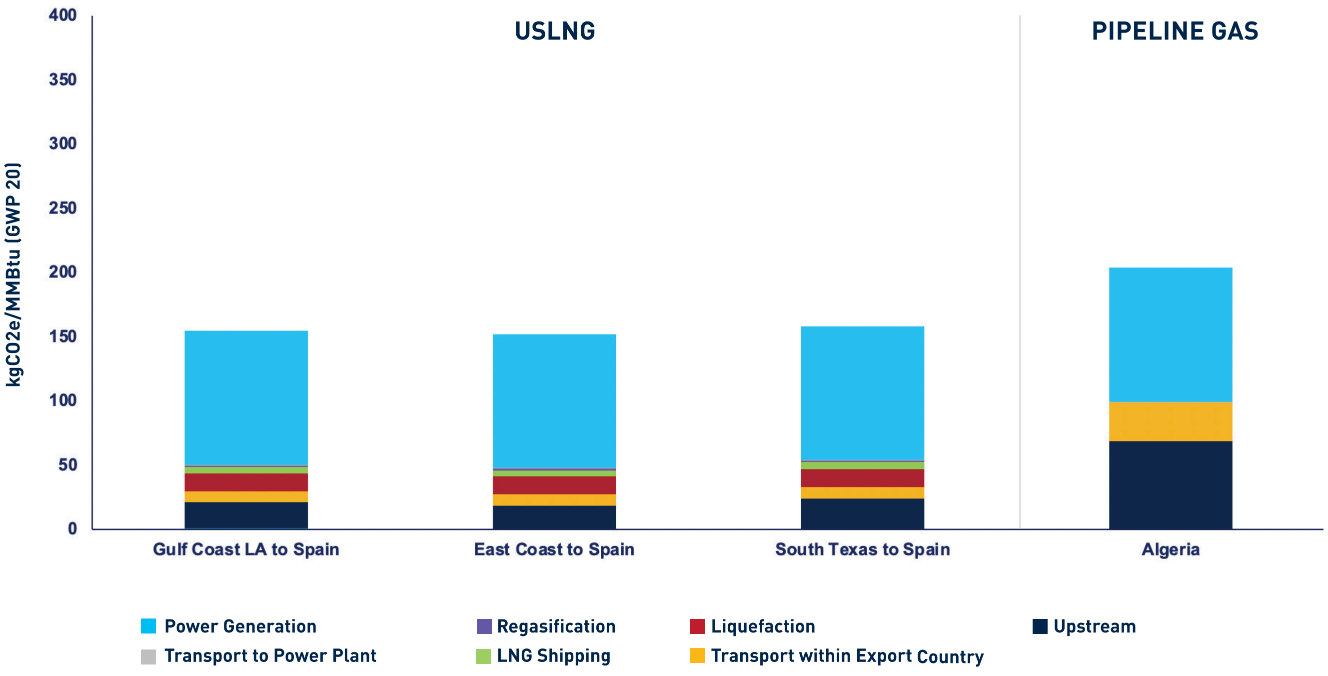
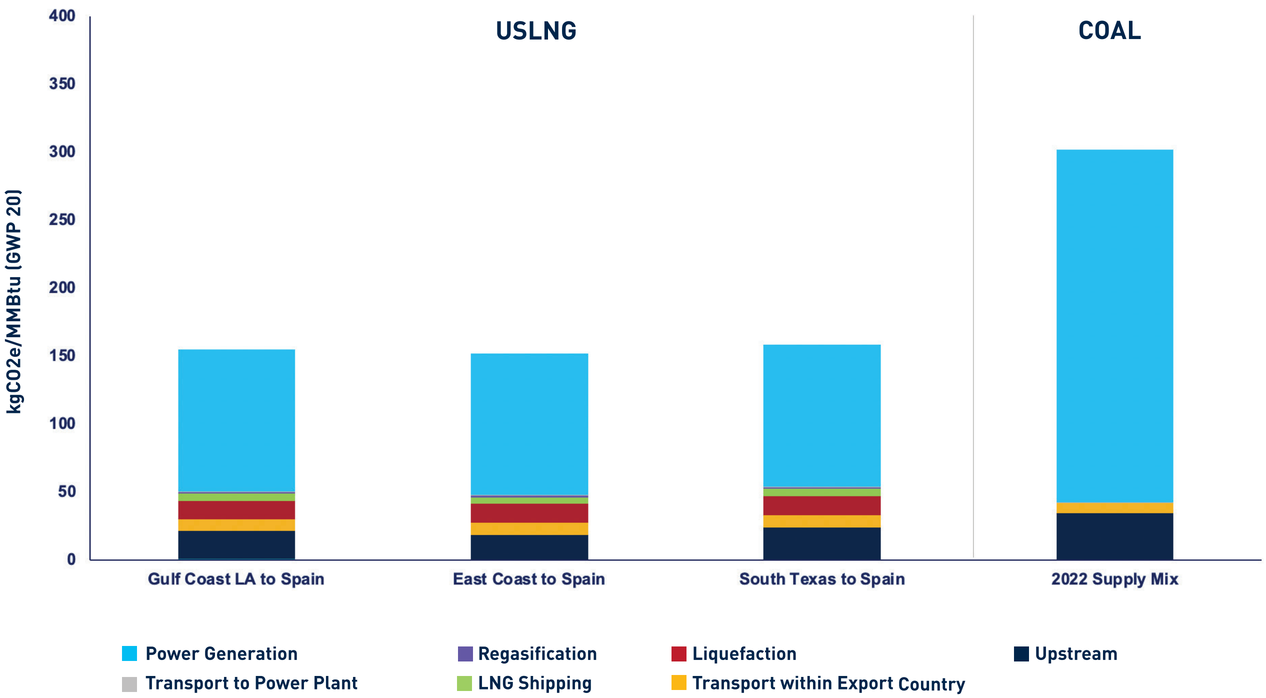


FIGURE 50: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG IMPORTS AND COAL SUPPLIES TO SPAIN



Türkiye

FIGURE 51: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG AND MAIN PIPELINE IMPORTS TO TÜRKIYE

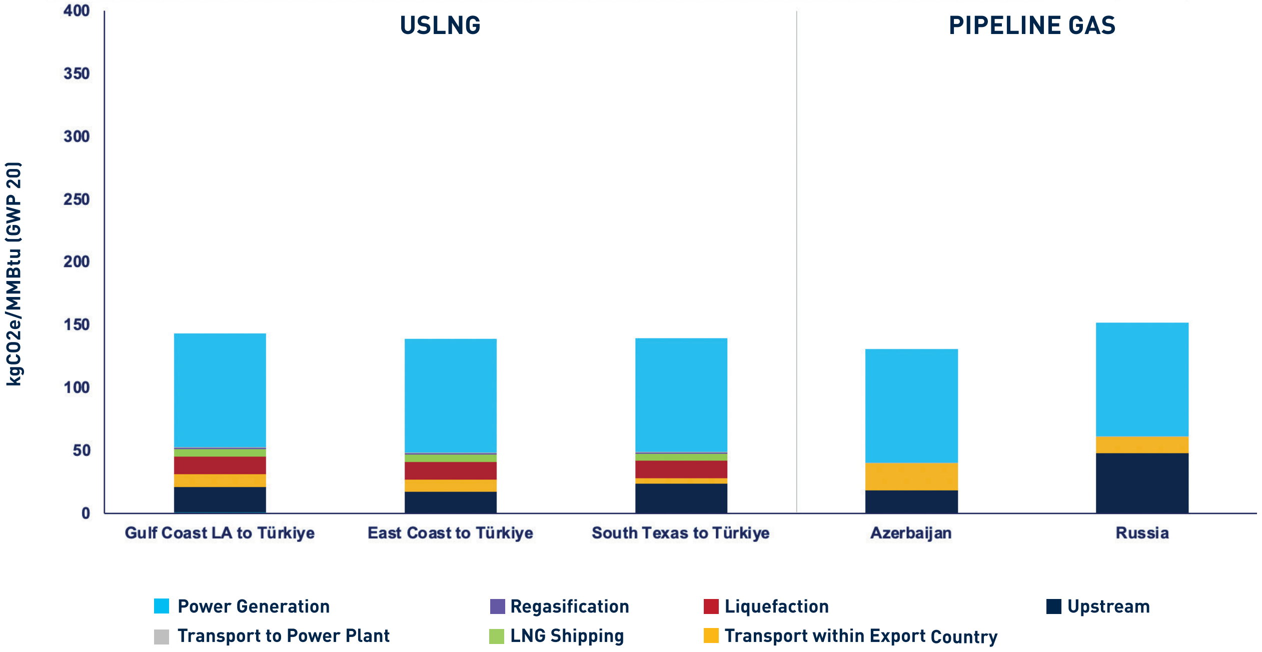
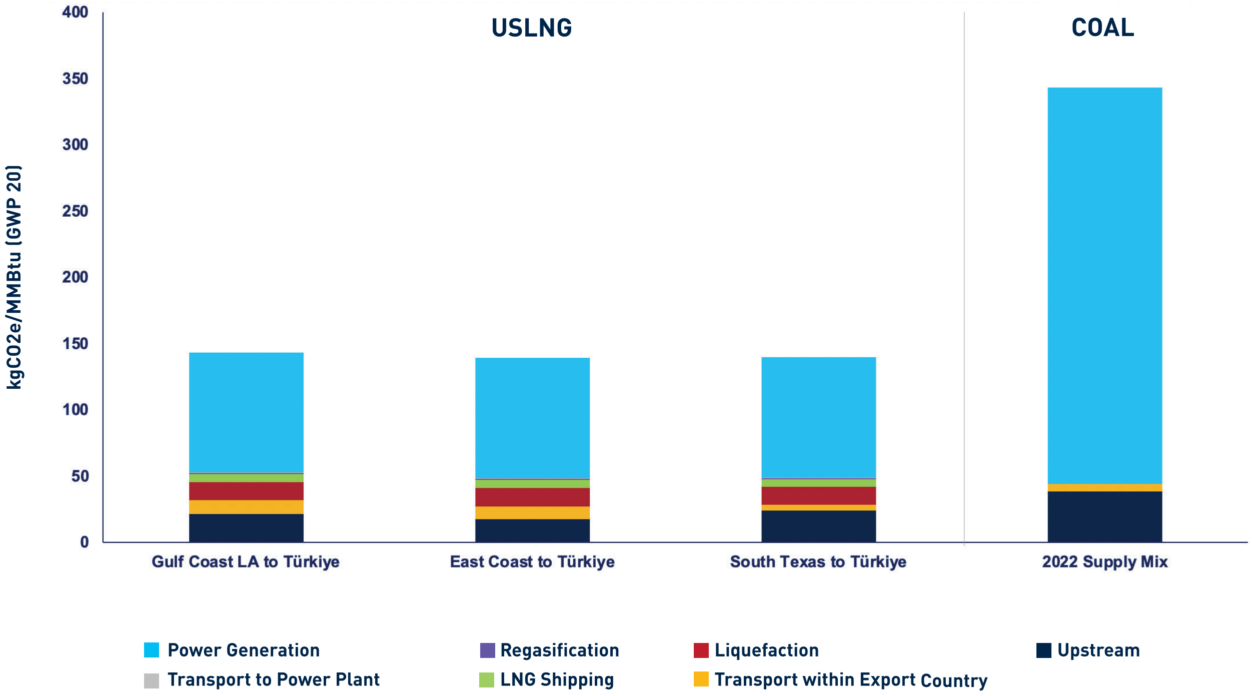


FIGURE 52: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG IMPORTS AND COAL SUPPLIES TO TÜRKIYE



United Kingdom

FIGURE 53: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG AND MAIN PIPELINE IMPORTS TO THE UNITED KINGDOM

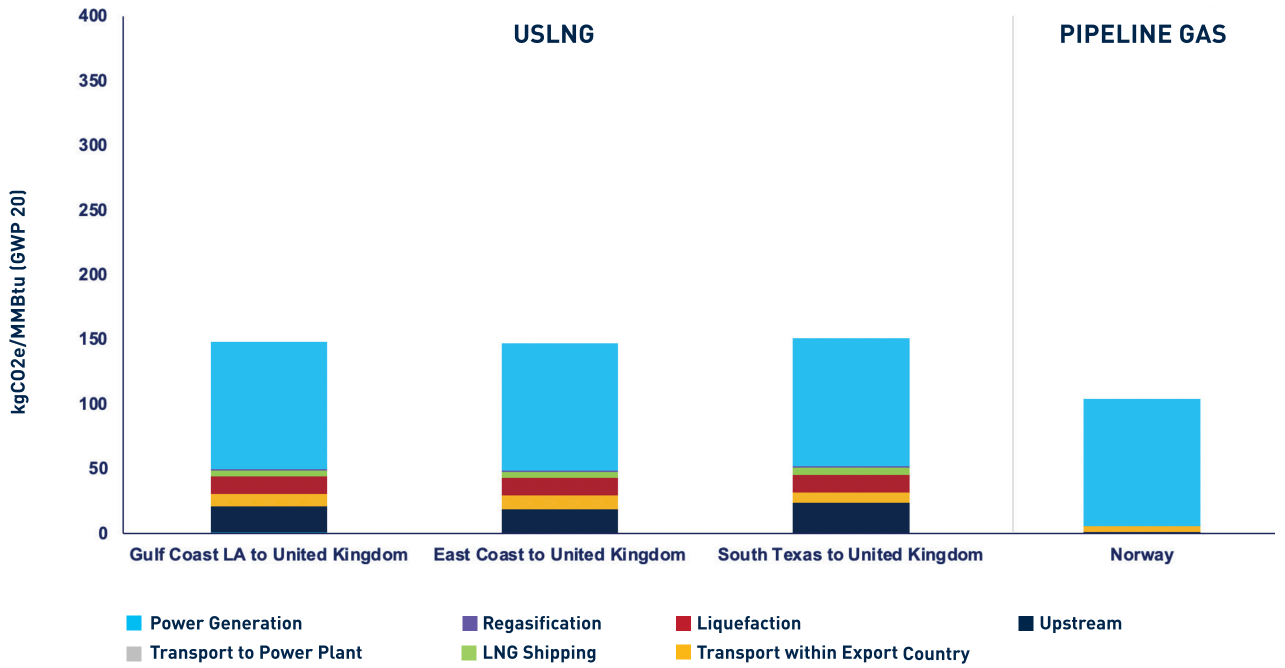
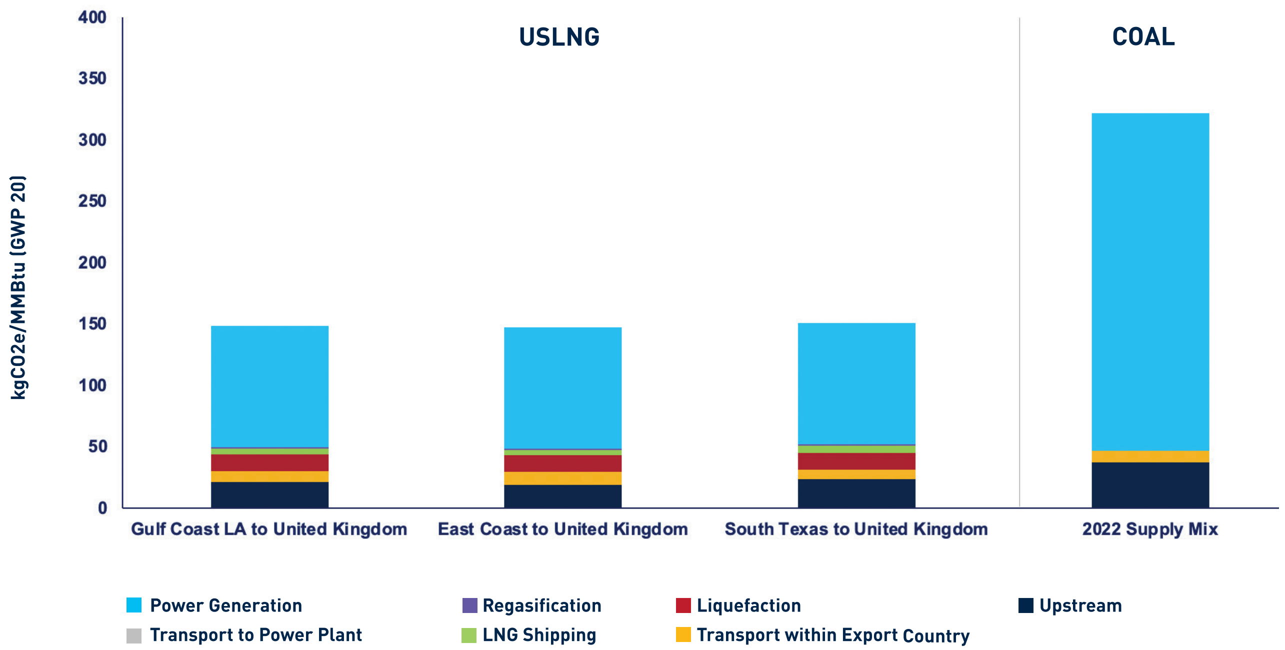


FIGURE 54: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG IMPORTS AND COAL SUPPLIES TO THE UNITED KINGDOM



China

FIGURE 55: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG AND MAIN PIPELINE IMPORTS TO CHINA

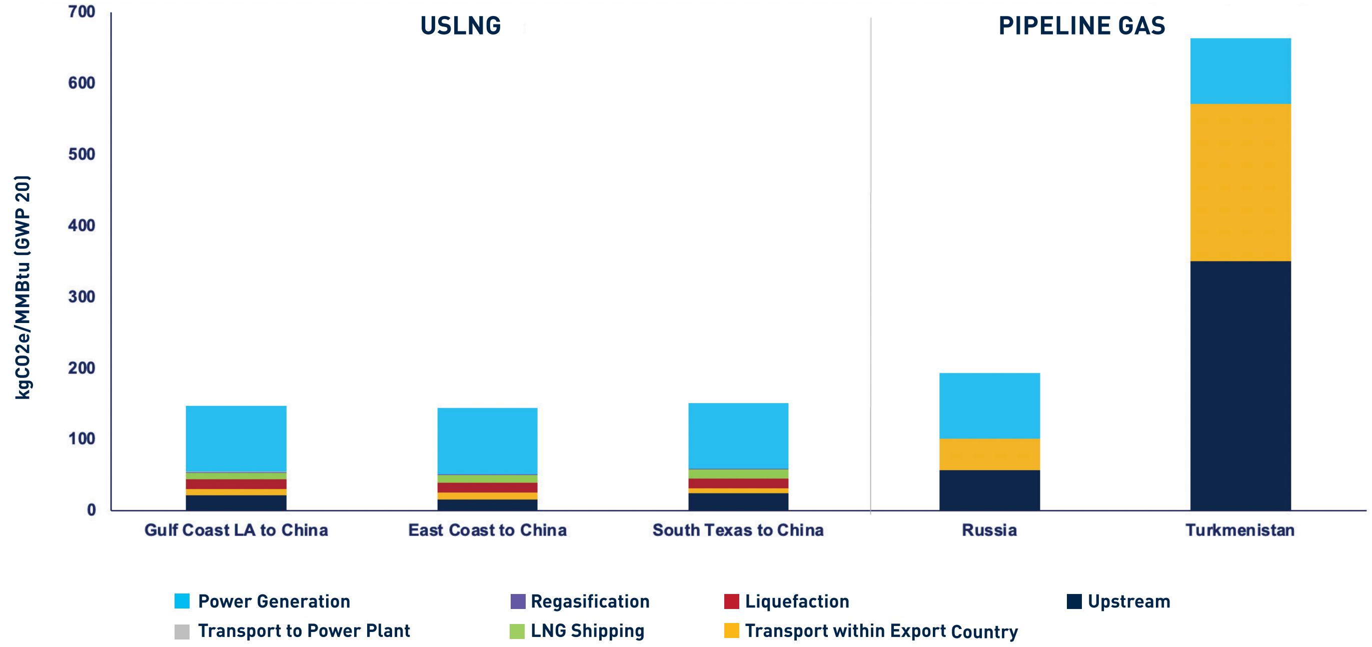
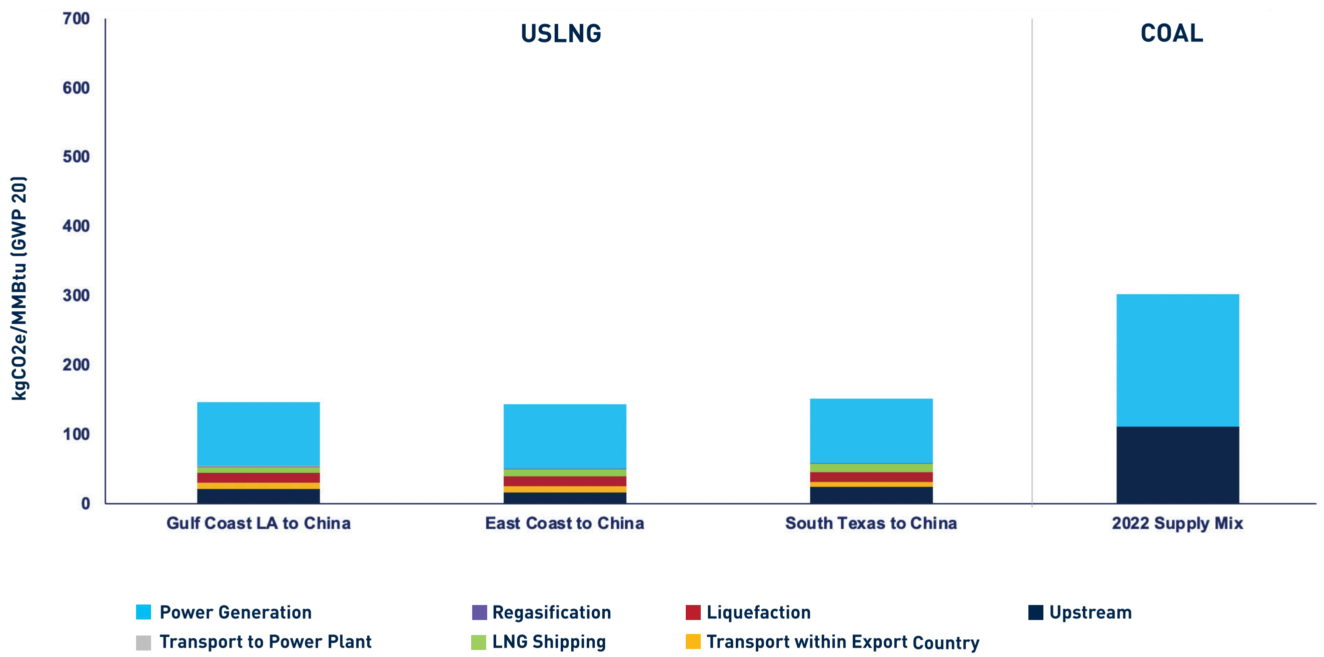
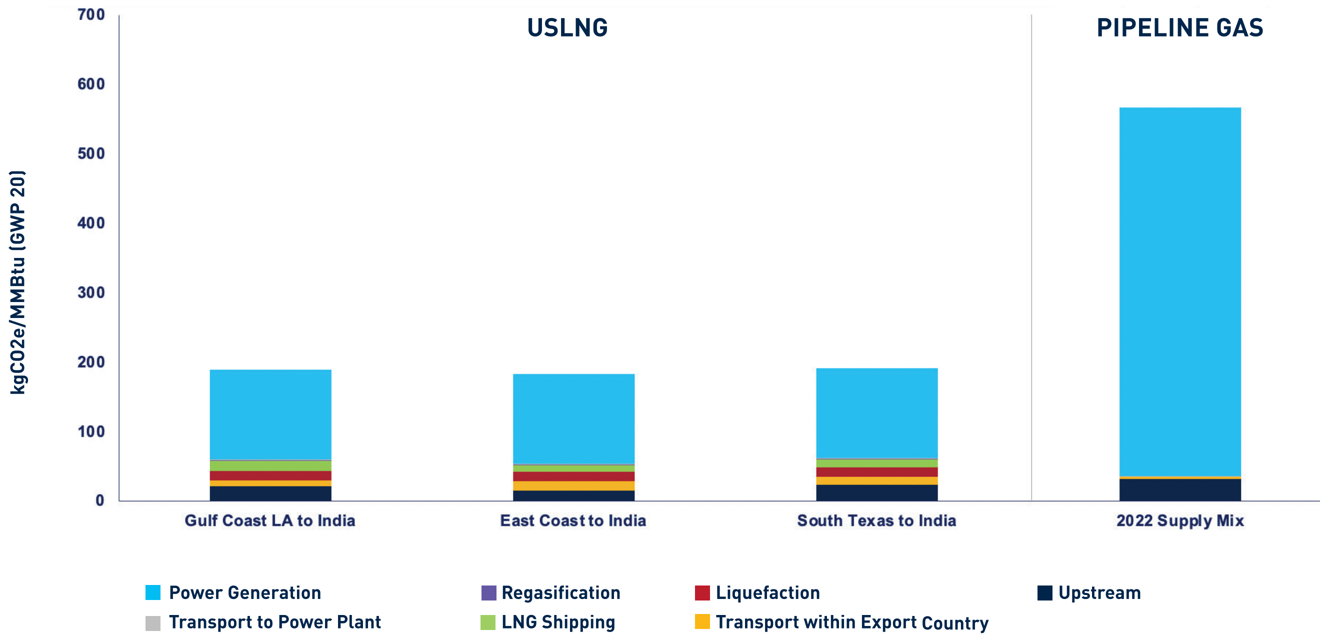


FIGURE 56: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG IMPORTS AND COAL SUPPLIES TO CHINA



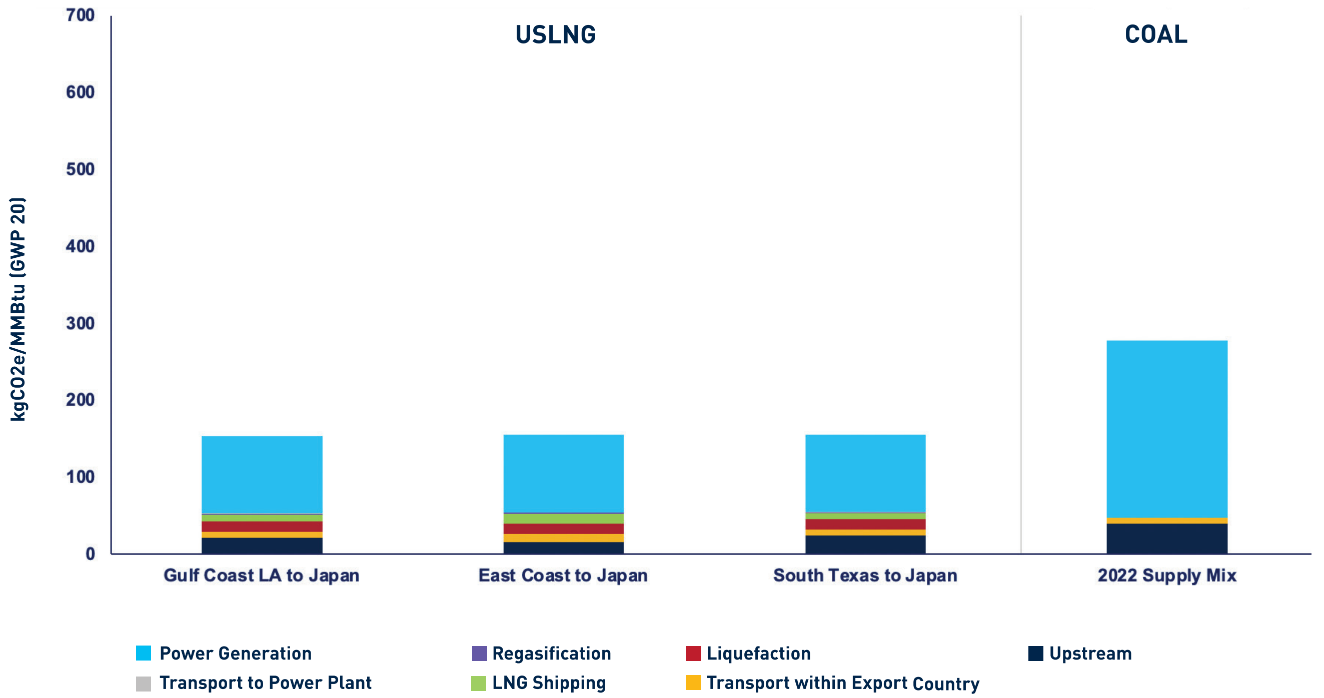
India

FIGURE 57: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG IMPORTS AND COAL SUPPLIES TO INDIA



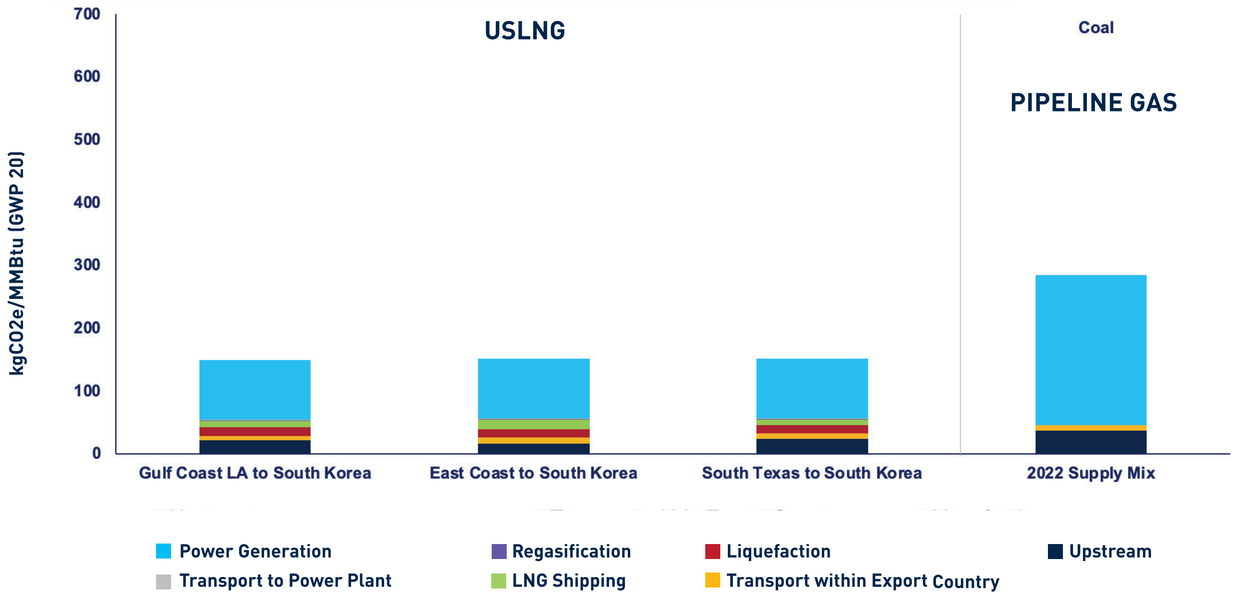
Japan

FIGURE 58: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG IMPORTS AND COAL SUPPLIES TO JAPAN



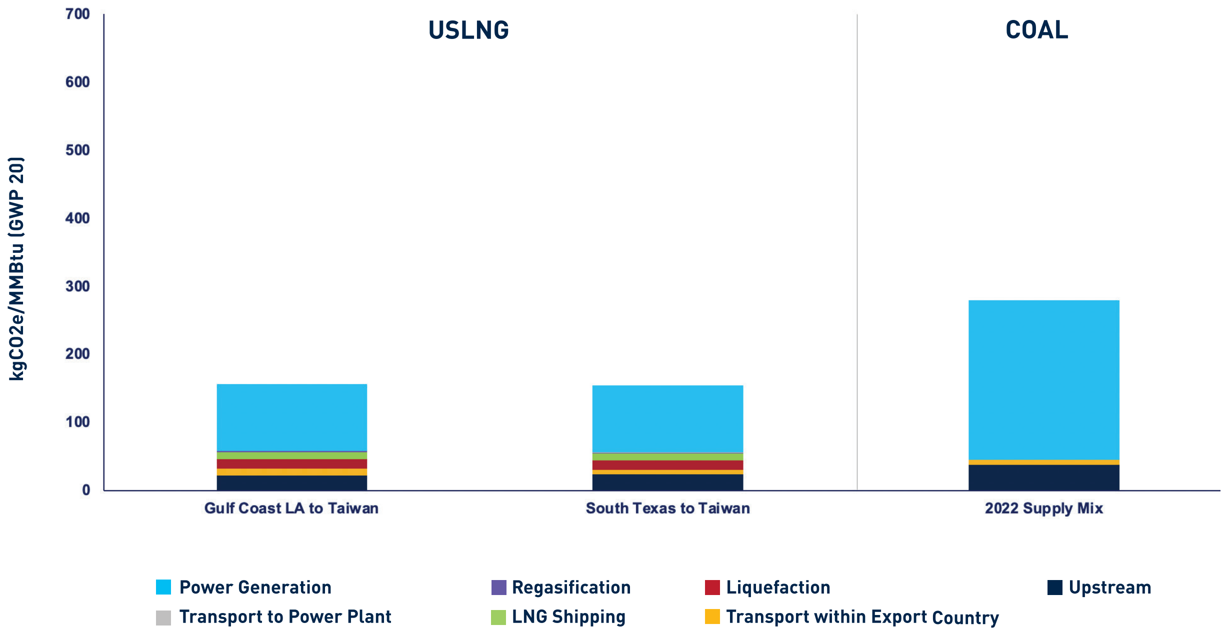
South Korea

FIGURE 59: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG IMPORTS AND COAL SUPPLIES TO SOUTH KOREA



Taiwan

FIGURE 60: COMPARISON OF GHG EMISSIONS INTENSITY OF USLNG IMPORTS AND COAL SUPPLIES TO TAIWAN



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