LNG Supply Chains: a supplier-specific life cycle assessment for improved emissions accounting
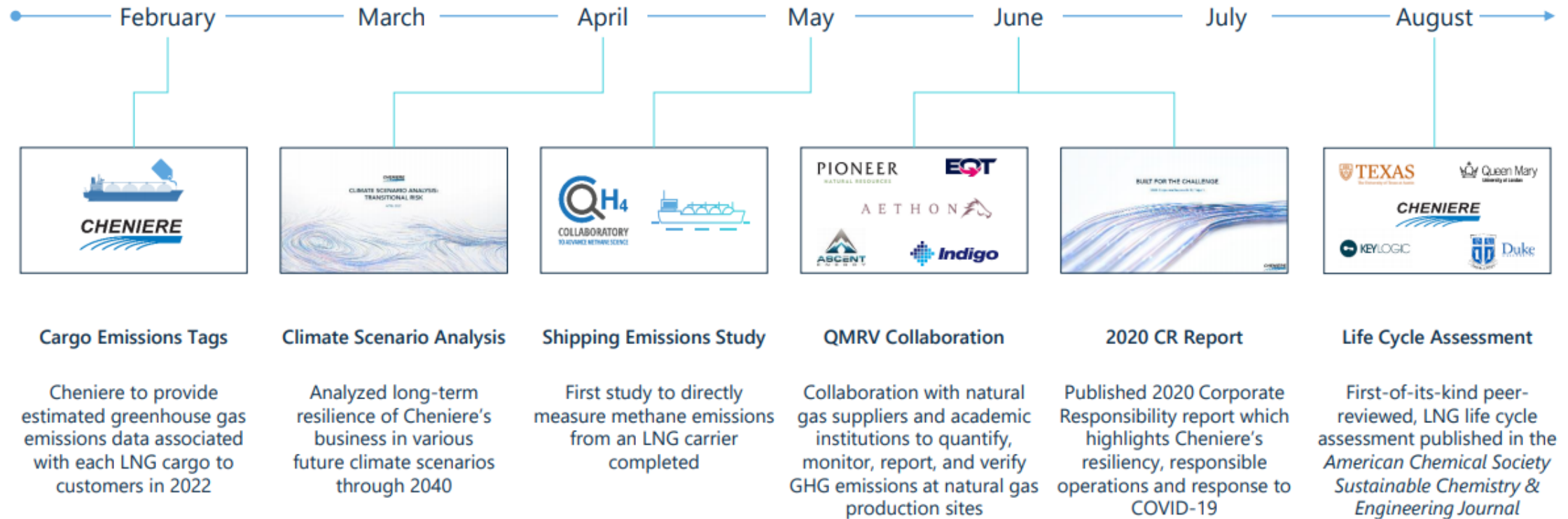
ACS Sustainable Chemistry & Engineering

September 9, 2021

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Built for the Challenge

Building a company that can **help meet the world's energy needs** while **integrating sustainability** into our business

February — March — April — May — June — July — August

Cargo Emissions Tags

Cheniere to provide estimated greenhouse gas emissions data associated with each LNG cargo to customers in 2022

Climate Scenario Analysis

Analyzed long-term resilience of Cheniere's business in various future climate scenarios through 2040

Shipping Emissions Study

First study to directly measure methane emissions from an LNG carrier completed

QMRV Collaboration

Collaboration with natural gas suppliers and academic institutions to quantify, monitor, report, and verify GHG emissions at natural gas production sites

2020 CR Report

Published 2020 Corporate Responsibility report which highlights Cheniere's resiliency, responsible operations and response to COVID-19

Life Cycle Assessment

First-of-its-kind peer-reviewed, LNG life cycle assessment published in the *American Chemical Society Sustainable Chemistry & Engineering Journal*

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Framework for customized life cycle GHG assessments for LNG supplies

ACS Sustainable Chemistry & Engineering

pubs.acs.org/journal/ascecg

Research Article

LNG Supply Chains: A Supplier-Specific Life-Cycle Assessment for Improved Emission Accounting
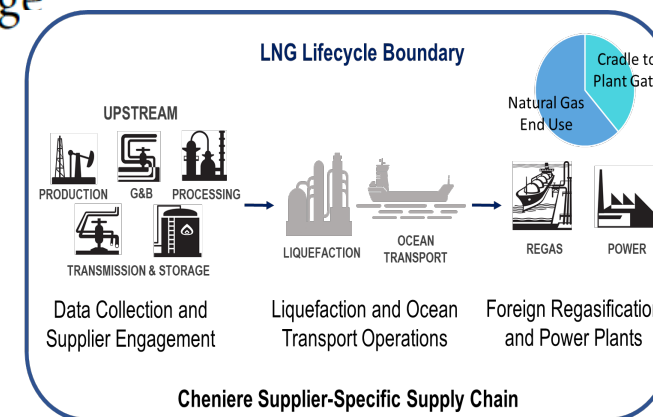
Selina A. Roman-White, James A. Littlefield, Kaitlyn G. Fleury, David T. Allen, Paul Balcombe, Katherine E. Konschnik, Jackson Ewing, Gregory B. Ross, and Fiji George*

Cite This: https://doi.org/10.1021/acssuschemeng.1c03307

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Key study findings

National or regional average supply chains do not accurately represent unique supply chains
- Individual supplier GHG performance varies significantly
- Our supply-chain specific GHG is 30-43% lower than other studies employing average values to estimate U.S. LNG emissions

Supply chain emissions upstream of end use are significant
- Upstream (prior to power plant) GHG emissions are> 30% of total GHG emissions on a CO_2e basis
- Methane emissions matter: ~ 8-18% of the total GHG emissions (100-yr to 20-yr basis)

Coal supply chains are also variable due to upstream methane emissions
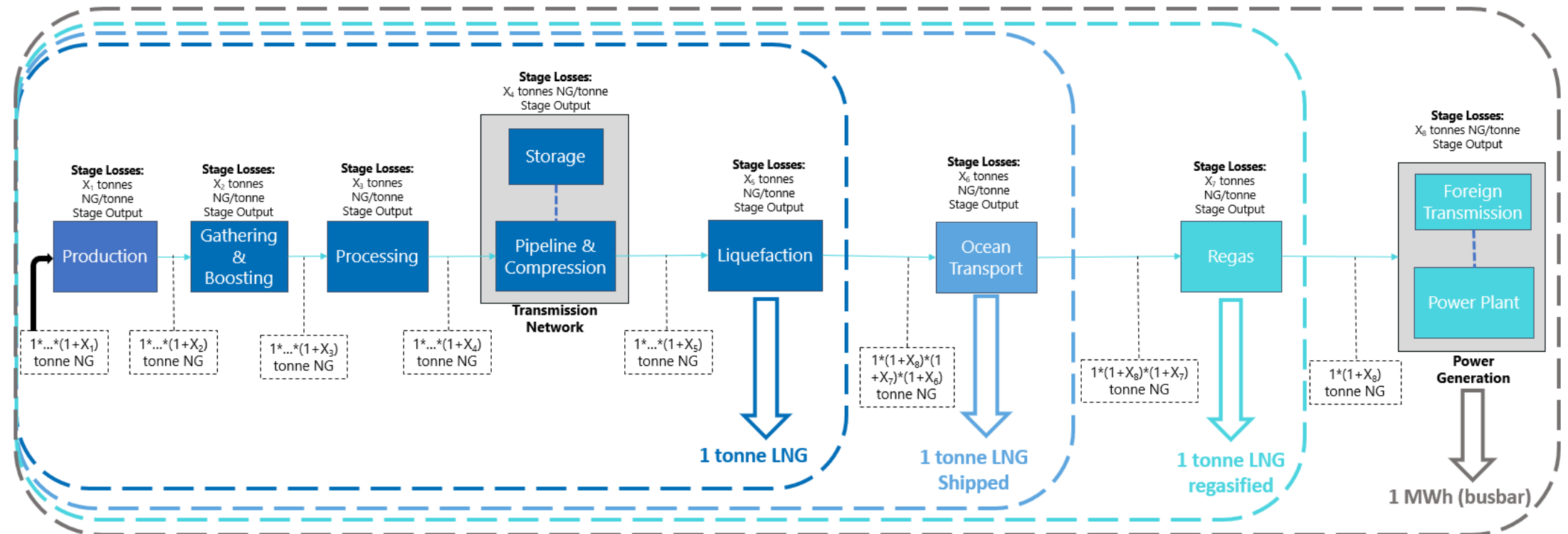- Characterizing this variability is important for quantifying the benefits of coal to gas switching

Characterizing the GHG intensity of specific gas supplies via LCAs is critical for informing differentiated gas supply, as well as informing policy and decision makers looking to develop climate strategies
- Ex: a 50% reduction in methane emissions results in 14-24% reduction in lifecycle emissions from production through liquefaction
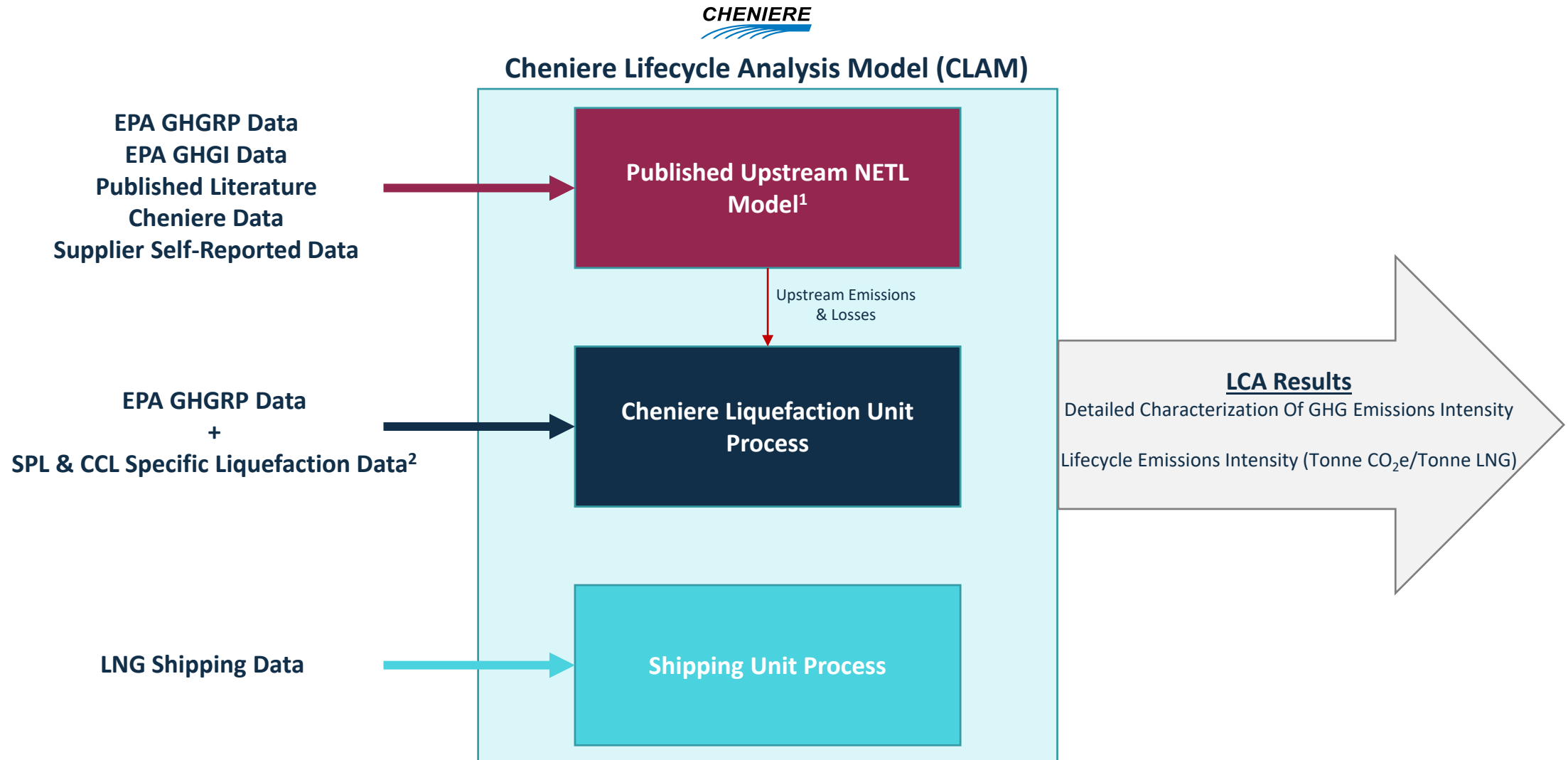
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LCA model concept

LCA modeling consistent with ISO 14040, 14044, and 14067

Built from the NETL LCA Model Framework and employs life cycle principles, not a simple aggregation of individual supplier inventories

LCA model structure

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Cheniere Lifecycle Analysis Model (CLAM)

EPA GHGRP Data
EPA GHGI Data
Published Literature
Cheniere Data
Supplier Self-Reported Data

Published Upstream NETL Model[1]

Upstream Emissions & Losses

EPA GHGRP Data
+
SPL & CCL Specific Liquefaction Data[2]

Cheniere Liquefaction Unit Process

LNG Shipping Data

Shipping Unit Process

LCA Results
Detailed Characterization Of GHG Emissions Intensity

Lifecycle Emissions Intensity (Tonne CO_2e/Tonne LNG)

1. National Energy Technology Laboratory (NETL) Lifecycle Model for upstream natural gas emissions. Model is data driven, highly parameterized, and open source. Includes emissions for production, gathering & boosting, processing, and transmission 2. Includes CO2 vented from the AGRUs that is not currently reported under the GHGRP program. Also includes electricity purchases where applicable

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Key differences between this study and NETL LNG Report

Upstream Supply Chain
Our study represents Cheniere's 2018 supply chain, and includes modeling updates to the latest state of the science, namely for gas flaring and transmission compression operations

Liquefaction
Our study models Sabine Pass Liquefaction operations, utilizing actual plant data and emissions reporting
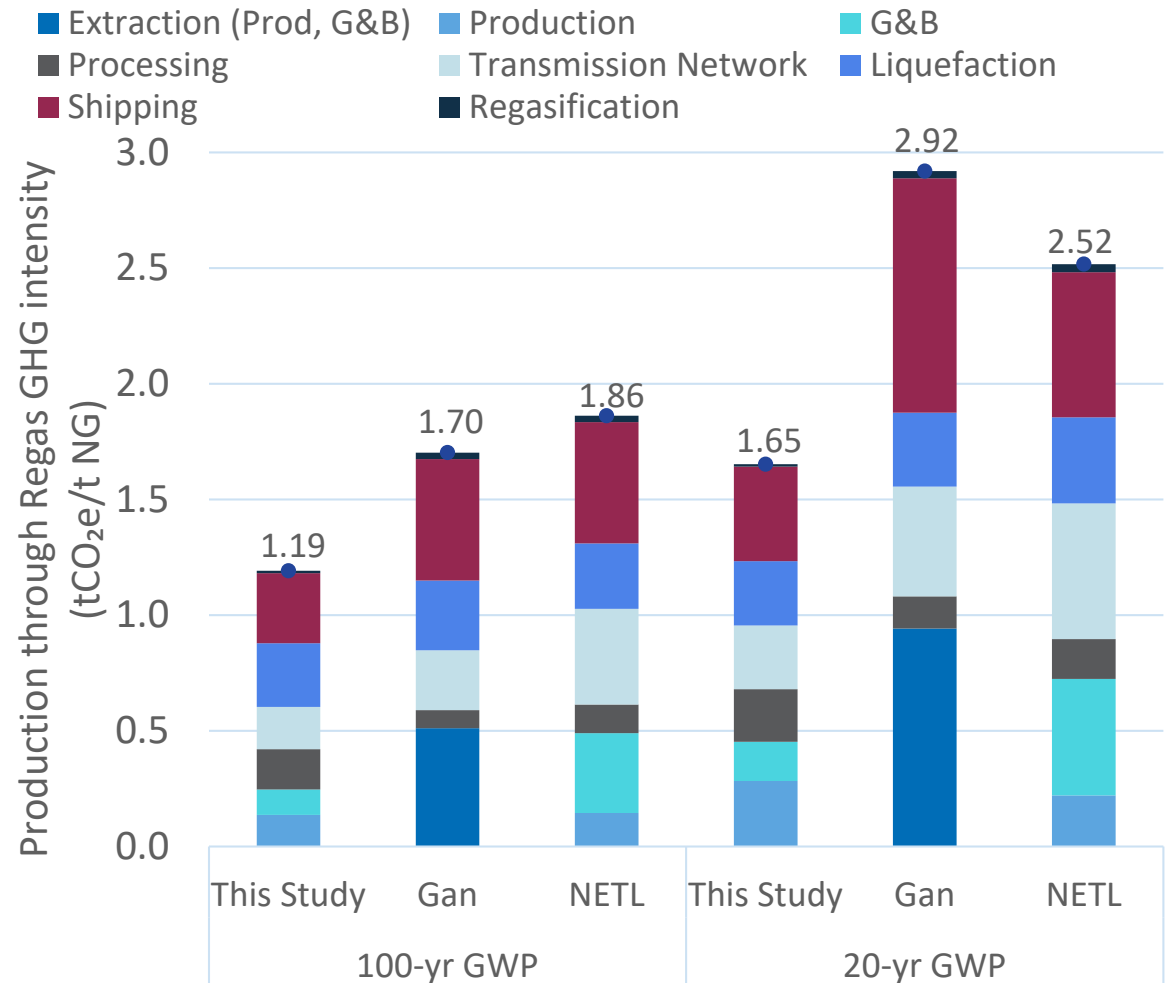
Ocean Transport
Our study employs a first of its kind customized ocean transport model that uses actual fuel consumption data supplemented with proprietary data sources, characterizing every cargo loaded at SPL in 2018

Power Generation
Our study employs market-specific natural gas power plant efficiencies calculated based on IEA reports, as well as includes the transmission pipeline between regasification and the power plant

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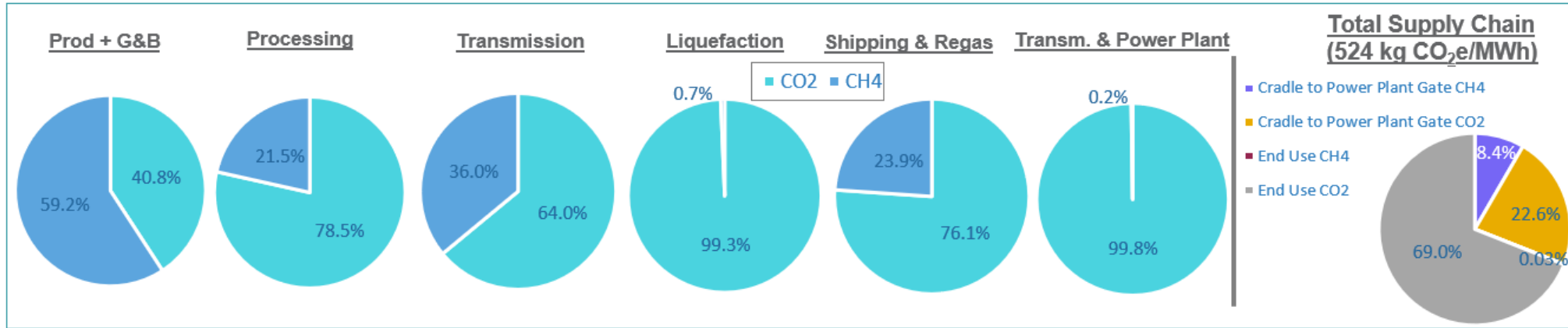# Supply chain accounting matters: production to regasification

- We compare our study to two other LNG studies that examined U.S. LNG exported to China

- We estimates a GHG intensity 30-43% lower than Gan et al. and NETL studies (100-yr to 20-yr GWP basis)

- Gan et al. and NETL employ national and regional average estimates to represent the supply chain. We find these estimates to not be representative of specific supply chains

- Key drivers of differences in GHG intensity are the production, G&B, transmission, and ocean transport stages
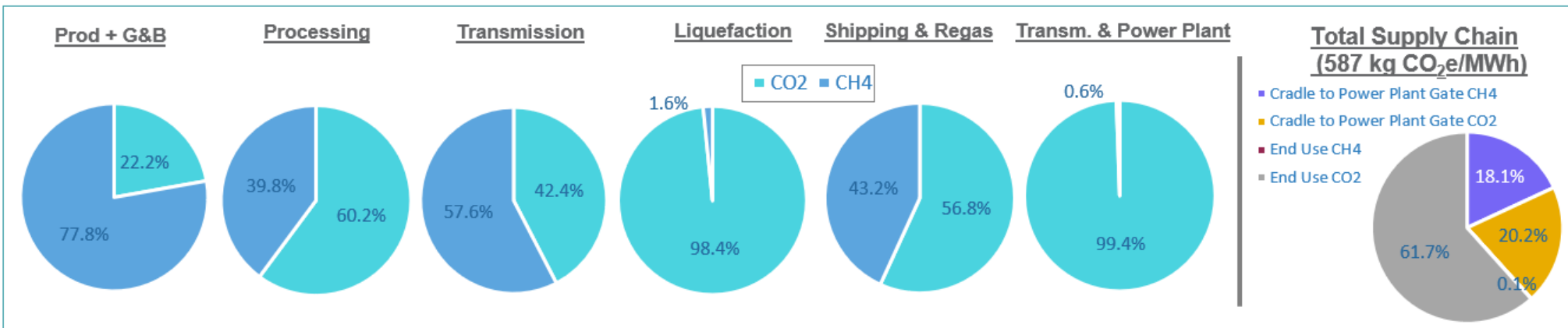

Legend:
- Extraction (Prod, G&B)
- Production
- G&B
- Processing
- Transmission Network
- Liquefaction
- Shipping
- Regasification

Y-axis: Production through Regas GHG intensity (tCO_2e/t NG)

100-yr GWP: This Study 1.19, Gan 1.70, NETL 1.86
20-yr GWP: This Study 1.65, Gan 2.92, NETL 2.52

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Methane vs. carbon dioxide across the supply chain

100-year CO_2 vs. CH_4 Life Cycle Emissions of Cheniere LNG Delivered to China (through busbar)

Prod + G&B: 59.2% / 40.8%
Processing: 21.5% / 78.5%
Transmission: 36.0% / 64.0%
Liquefaction: 0.7% / 99.3%
Shipping & Regas: 23.9% / 76.1%
Transm. & Power Plant: 0.2% / 99.8%

Legend: CO2 / CH4

Total Supply Chain (524 kg CO_2e/MWh)
- Cradle to Power Plant Gate CH4
- Cradle to Power Plant Gate CO2
- End Use CH4
- End Use CO2

8.4% / 22.6% / 0.03% / 69.0%

20-year CO_2 vs. CH_4 Life Cycle Emissions of Cheniere LNG Delivered to China (through busbar)

Prod + G&B: 77.8% / 22.2%
Processing: 39.8% / 60.2%
Transmission: 57.6% / 42.4%
Liquefaction: 1.6% / 98.4%
Shipping & Regas: 43.2% / 56.8%
Transm. & Power Plant: 0.6% / 99.4%

Legend: CO2 / CH4

Total Supply Chain (587 kg CO_2e/MWh)
- Cradle to Power Plant Gate CH4
- Cradle to Power Plant Gate CO2
- End Use CH4
- End Use CO2

18.1% / 20.2% / 0.1% / 61.7%

Production through Liquefaction CH_4 Emission Rate: 0.65%

Production through Shipping CH_4 Emission Rate: 0.90%

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Market customization

Production through Ocean Transport GHG Intensity (tCO2e/tLNG delivered, 100-yr GWP)
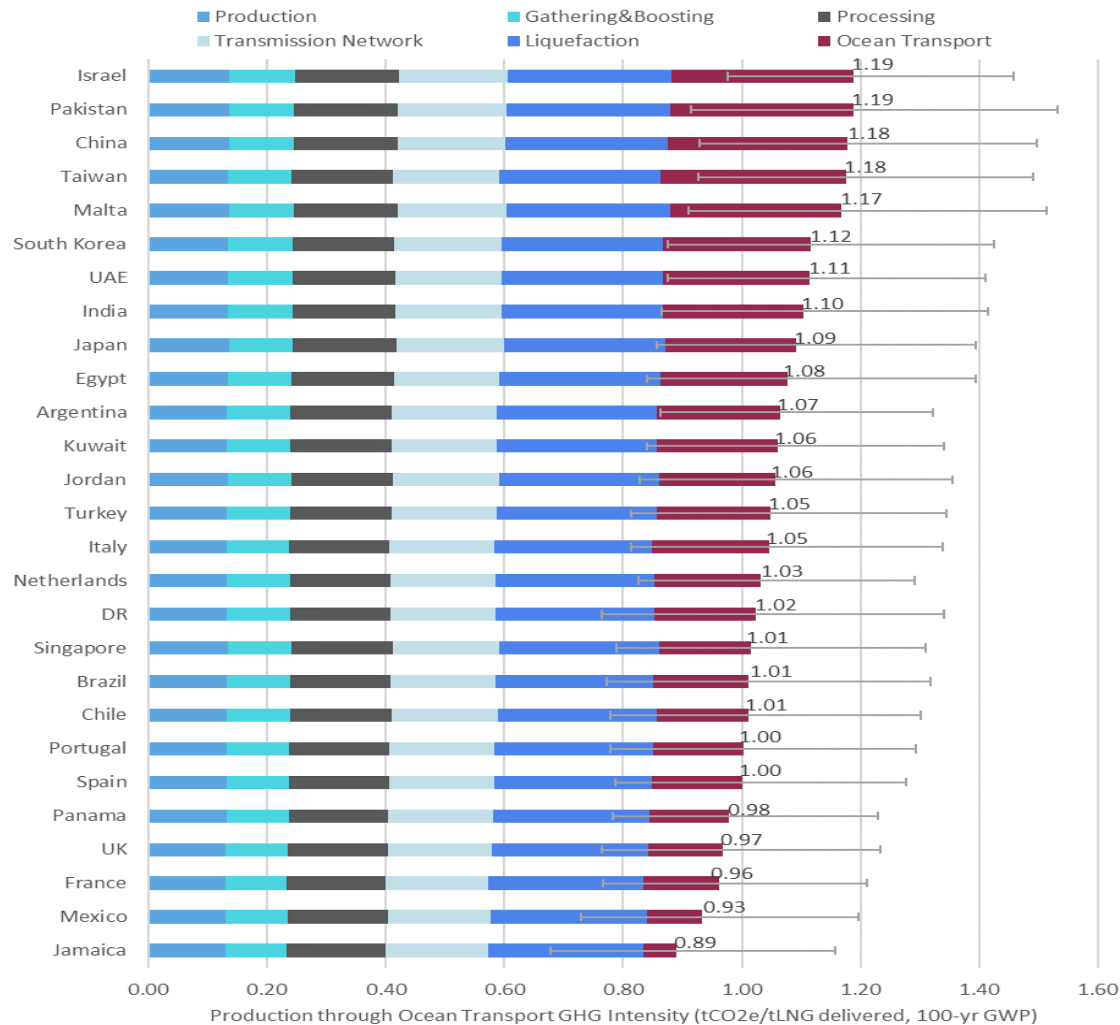
We estimate the average GHG intensity on a DES basis (production through ocean transport) for each market served in 2018
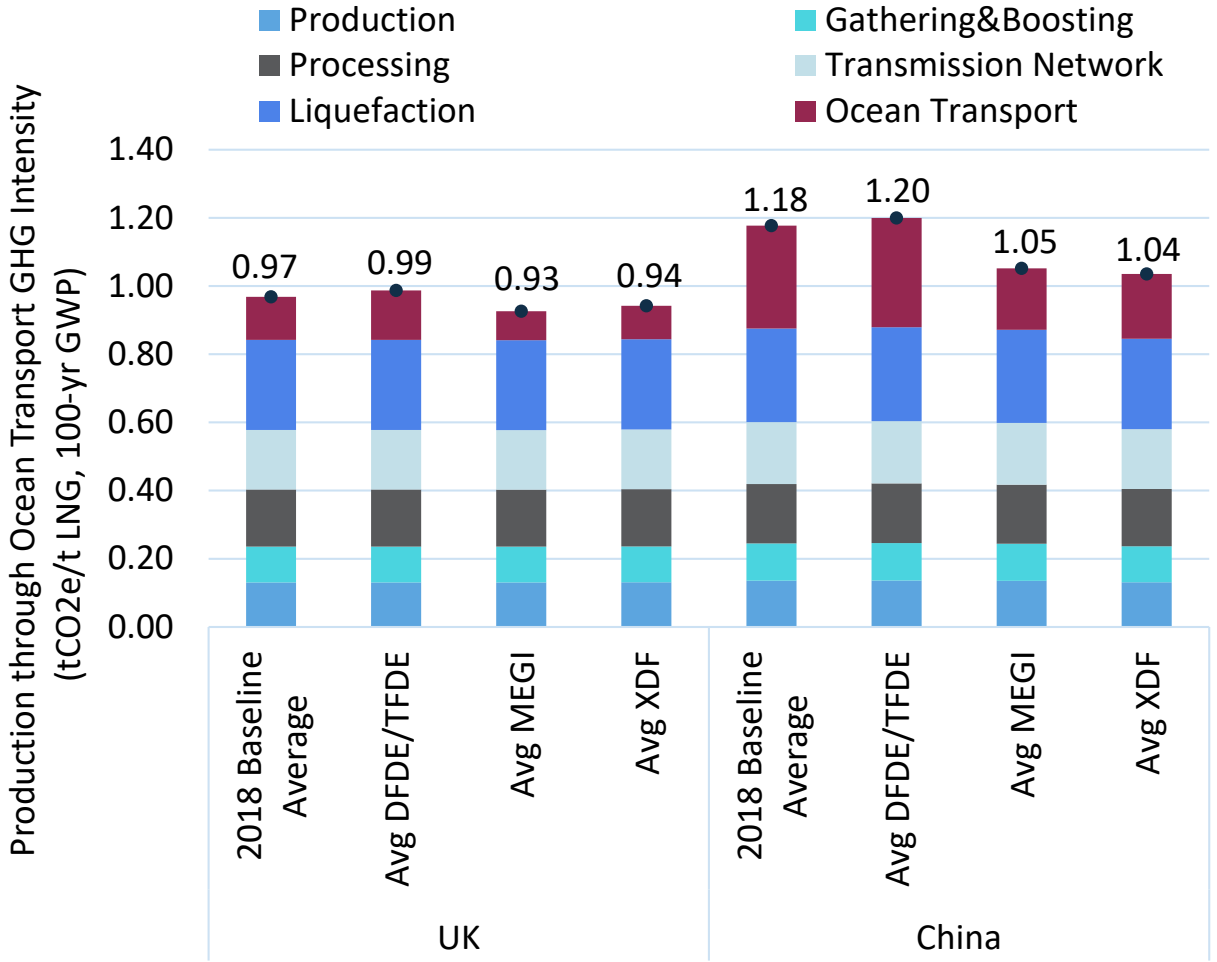
- We model a round trip voyage (laden and ballast)

Within a market, there is variability between the GHG intensity of individual cargoes due to voyage duration and **differences in vessel performance**

- Neighboring countries have different profiles – **voyage duration alone cannot explain this**
- The differences in ocean transport intensity are driven by a combination of voyage distance and propulsion system of the LNG carrier (performance)
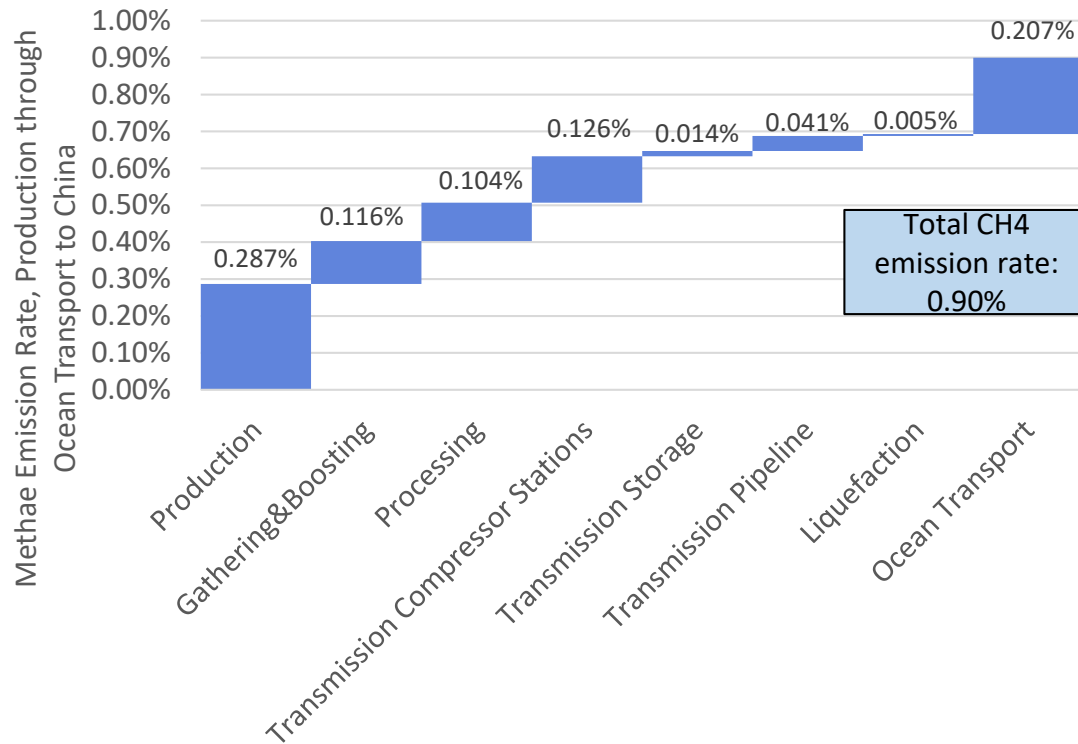
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Vessel choice: case study

- The importance of vessel choice is magnified over longer distances

- For the UK, the difference between DFDE/TFDE cargoes (high slip, lower efficiency) and XDF cargoes (lower slip, higher efficiency) is only 5%

- For China, the difference is a 14% lower GHG intensity on a DES basis

- Additional work is necessary to better understand methane slip rates in main propulsion and auxiliary engines
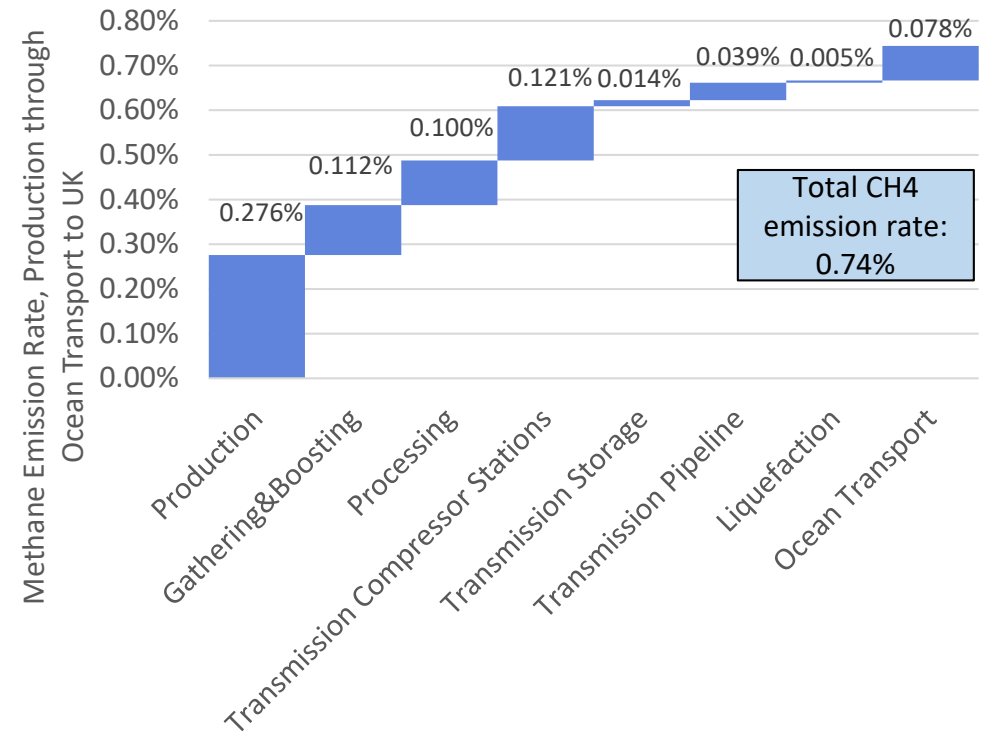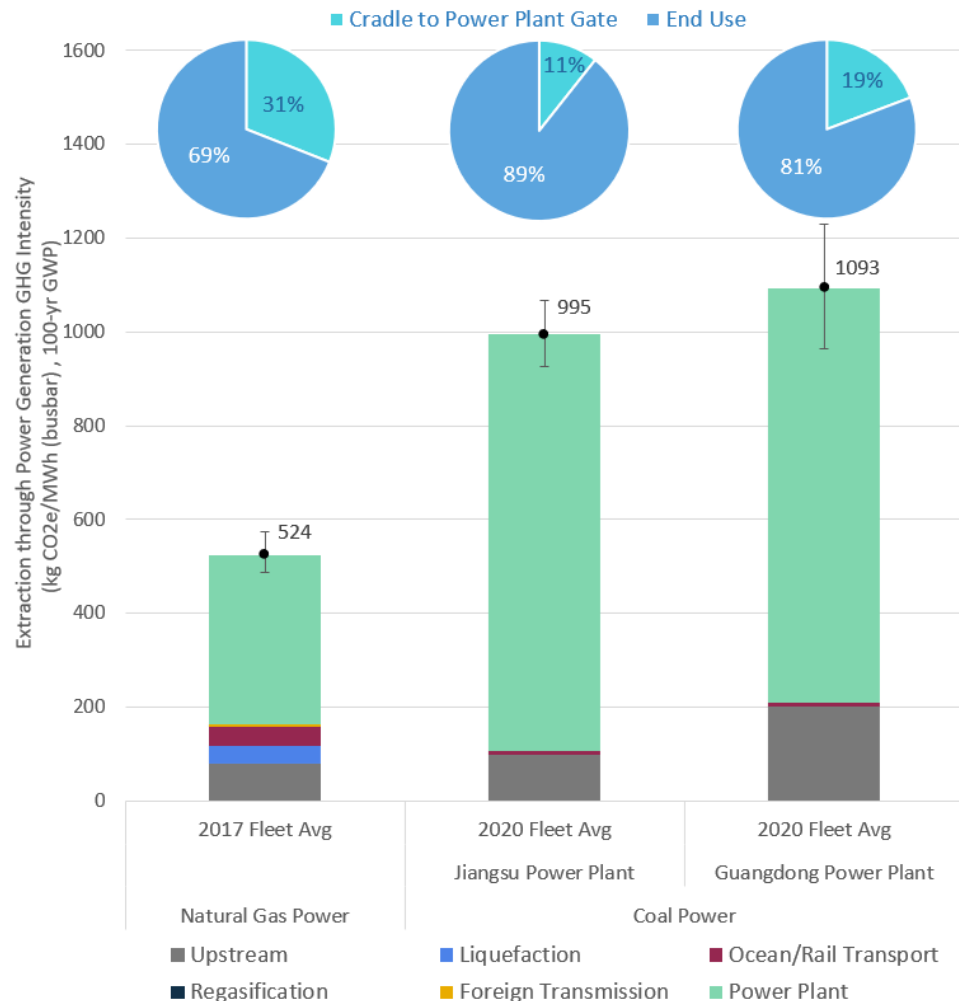
Methane emissions intensity

LNG Exported to China: CH$_4$ Emission Rate

Methae Emission Rate, Production through Ocean Transport to China

- Production: 0.287%
- Gathering&Boosting: 0.116%
- Processing: 0.104%
- Transmission Compressor Stations: 0.126%
- Transmission Storage: 0.014%
- Transmission Pipeline: 0.041%
- Liquefaction: 0.005%
- Ocean Transport: 0.207%

Total CH4 emission rate: 0.90%

LNG Exported to UK: CH$_4$ Emission Rate

Methane Emission Rate, Production through Ocean Transport to UK

- Production: 0.276%
- Gathering&Boosting: 0.112%
- Processing: 0.100%
- Transmission Compressor Stations: 0.121%
- Transmission Storage: 0.014%
- Transmission Pipeline: 0.039%
- Liquefaction: 0.005%
- Ocean Transport: 0.078%

Total CH4 emission rate: 0.74%

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Quantifying coal to gas switching benefits: China case study

- We used the latest published science to estimate the GHG intensity of coal-fired power generation in China

- Recent studies have shown that coal mine methane may be much more significant than previously thought, and highly variable

- Quantifying CMM emissions for specific coal supply chains will be important for understanding the benefits of coal to gas switching

- We estimate Cheniere's LNG exported to China for power generation to be 47-57% less GHG intense than coal power generation on an equivalent MWh basis (100-yr and 20-yr GWP basis)
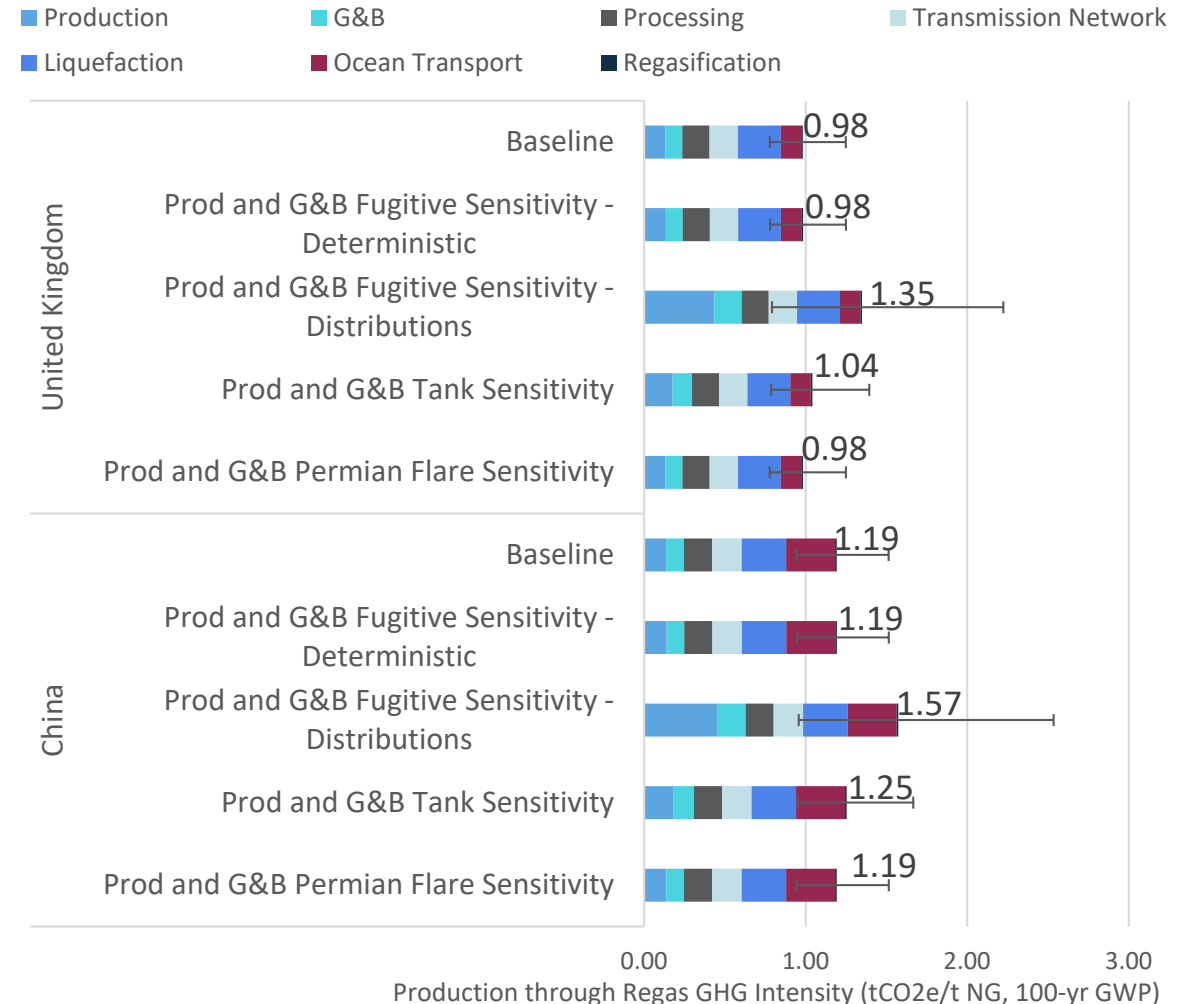
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Sensitivity to methane emission rate

- Cheniere's 2018 SPL baseline methane emission rate is 0.65% (production through liquefaction)

- We conducted a sensitivity analysis to measured the impact of upstream (production through transmission) methane emission reduction on the overall profile

- The sensitivity was technology agnostic

- We estimate that a 50% reduction in upstream methane would result in a 14% reduction in 100-yr GHG CO_2e intensity, and a 24% reduction on a 20-yr GWP basis

Methane Emission Rate
Baseline: 0.65%
25% reduction: 0.49%
50% reduction: 0.33%
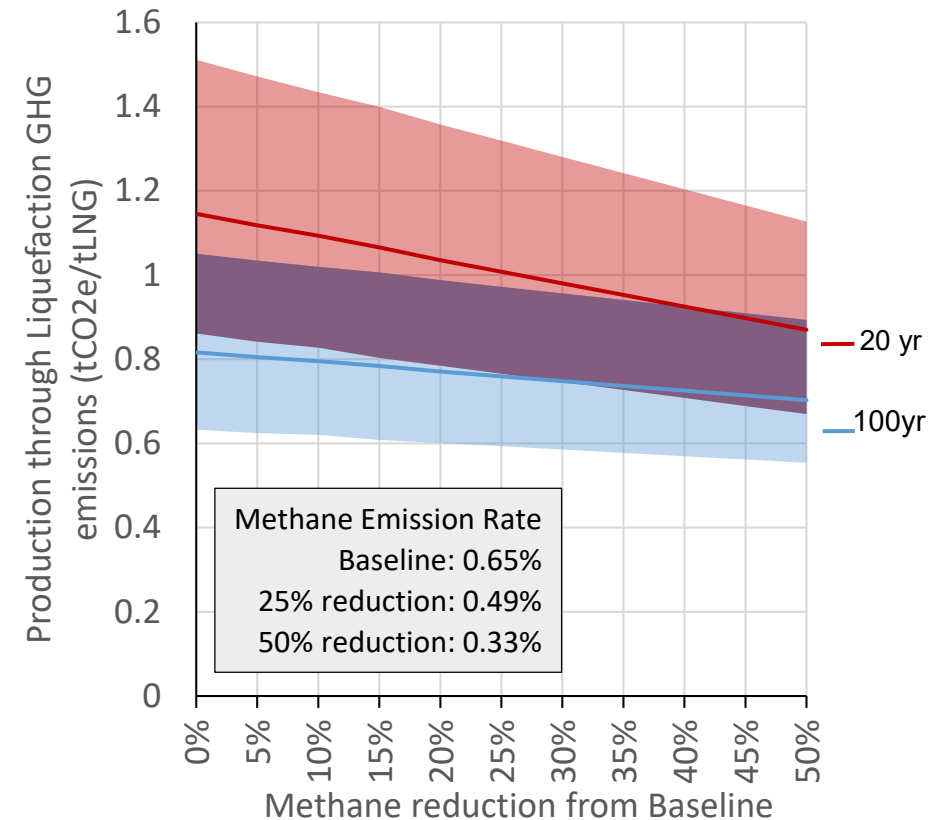
Sensitivity to underreporting in the GHGRP Inventory

- We estimated the impact of certain modeling decisions on the LCA result, using the UK and China as case studies

- We use recent work by Lyon et al. and Rutherford et al. to look at Permian flaring efficiency, Production and G&B fugitive emissions, and Production and G&B tanks

- On a cradle through regas basis, the impact ranges from less than 1% to 37% from the baseline depending on parameter

- These sensitivity results do not impact the fundamental conclusions of this study, the modeling framework is data agnostic and still valid for customized LCA of LNG supply chains

Legend: Production, G&B, Processing, Transmission Network, Liquefaction, Ocean Transport, Regasification

United Kingdom
- Baseline: 0.98
- Prod and G&B Fugitive Sensitivity - Deterministic: 0.98
- Prod and G&B Fugitive Sensitivity - Distributions: 1.35
- Prod and G&B Tank Sensitivity: 1.04
- Prod and G&B Permian Flare Sensitivity: 0.98

China
- Baseline: 1.19
- Prod and G&B Fugitive Sensitivity - Deterministic: 1.19
- Prod and G&B Fugitive Sensitivity - Distributions: 1.57
- Prod and G&B Tank Sensitivity: 1.25
- Prod and G&B Permian Flare Sensitivity: 1.19

Production through Regas GHG Intensity (tCO2e/t NG, 100-yr GWP)

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Policy implications

Customized LCA models are needed to assess the intensities of different gas supplies for policy and commercial considerations

- There are wide variations in emission intensities across different supply chains
- Use of generic or regional emissions data, or simply an aggregation of inventory estimates in each segment does not provide an accurate representation of emissions
- All relevant emission sources and segments of the supply chain should be considered
- Our LCA model provides a framework for improved GHG accounting

CO_2 is the dominant GHG source from "cradle to busbar" but CH_4 matters

- Key segments: production, gathering & boosting, transmission and shipping segments

LCA modeling provides customers and policymakers the information to integrate climate and trade/commercial policies
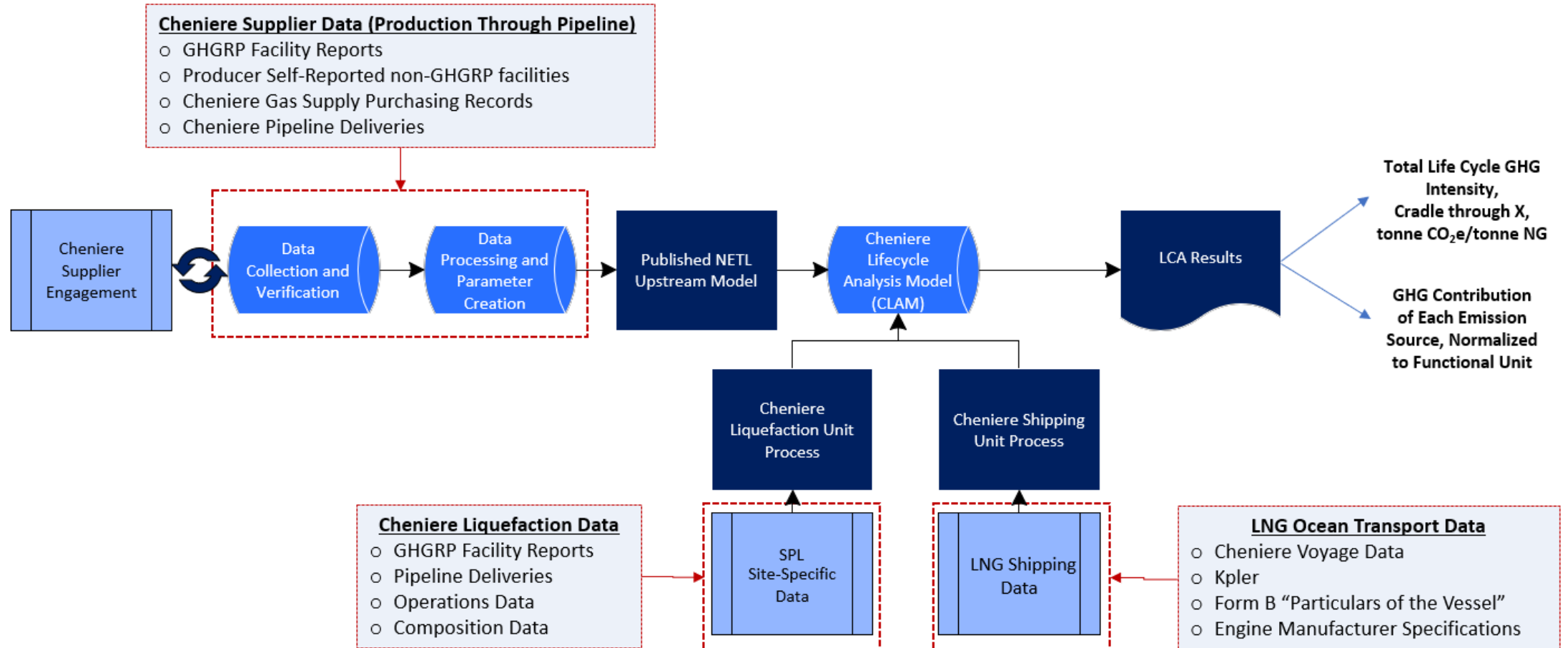
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Thank you

Questions?

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Appendix

Methods and data sources

Backup slides – detailed results tables

Baseline Production through Liquefaction Results, tonne CO_2e/tonne LNG

Stage	100-yr GWP	20-yr GWP
Production	0.13	0.26
Gathering & Boosting	0.10	0.16
Processing	0.16	0.21
Transmission Compressor Stations	0.15	0.21
Transmission Storage	0.01	0.02
Transmission Pipeline	0.01	0.03
Liquefaction	0.26	0.26
Total	0.82	1.15
P2.5	0.63	0.86
P97.5	1.05	1.51

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Backup slides – detailed results tables

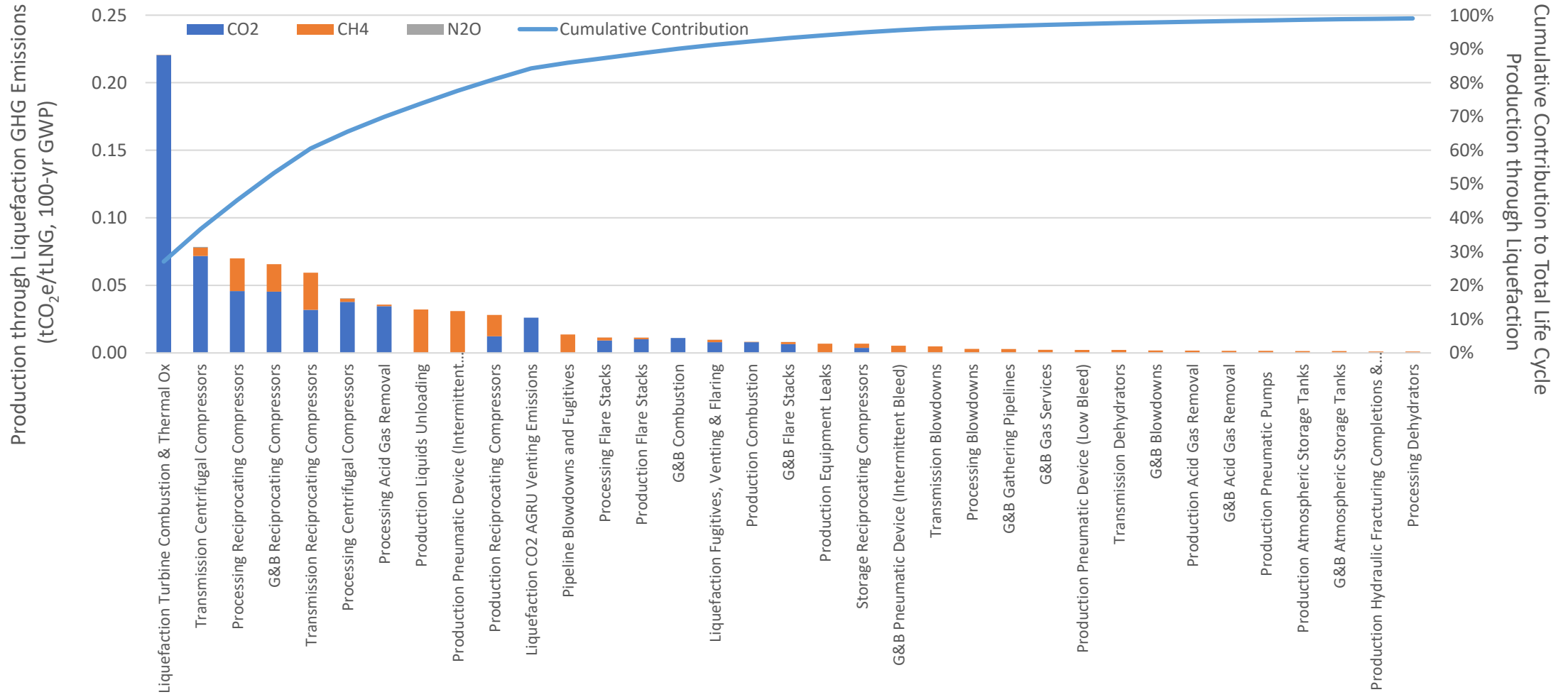*Baseline Production through Regasification Results, tonne CO_2e/tonne natural gas regasified*

Stage	United Kingdom		China	
	100-yr GWP	20-yr GWP	100-yr GWP	20-yr GWP
Production	0.13	0.27	0.14	0.28
Gathering & Boosting	0.11	0.16	0.11	0.17
Processing	0.17	0.22	0.17	0.23
Transmission Compression	0.15	0.21	0.16	0.22
Transmission Storage	0.01	0.02	0.01	0.02
Transmission Pipeline	0.01	0.03	0.01	0.04
Liquefaction	0.27	0.27	0.28	0.28
Ocean Transport	0.13	0.17	0.30	0.41
Regasification	0.01	0.01	0.01	0.01
Total	0.98	1.36	1.19	1.65
P2.5	0.78	1.05	0.94	1.28
P97.5	1.25	1.77	1.51	2.13

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Backup slides – detailed results tables

Baseline Production through Power Generation Results, kg CO$_2$e/MWh (busbar)

Stage	United Kingdom		China	
	100-yr GWP	20-yr GWP	100-yr GWP	20-yr GWP
Production	18.4	38.3	18.1	37.6
Gathering & Boosting	14.9	22.9	14.6	22.5
Processing	23.7	30.9	23.2	30.3
Transmission Compression	21.4	30.1	21.0	29.5
Transmission Storage	1.3	2.3	1.3	2.3
Transmission Pipeline	2.0	4.8	1.9	4.7
Liquefaction	37.3	37.7	36.6	36.9
Ocean Transport	17.9	23.5	40.3	54.3
Regasification	1.4	1.4	1.3	1.3
Foreign Transmission	2.8	3.3	4.1	5.1
Power Generation	384.7	384.9	361.9	362.1
Total	525.7	580.0	524.4	586.8
P2.5	492.5	531.3	485.9	531.2
P97.5	567.6	642.3	573.2	657.9

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Backup slides – drilldowns

Backup slides – drilldowns