On-line only supplemental materials:

Supplemental Table A. Methane emissions from both upstream and downstream associated with natural gas production in the Permian Basin for 8 campaigns as presented in Sherwin et al. (2024).

Campaign	upstream emissions (tons/hr) [a]	midstream emissions (tons/hr) [b]	total emissions (tons/hr)	production (tons/hr) [c]	percent emitted
Kairos NM Permian	48.8	78.9	127.7	1,952	6.5 %
CM Permian/2019	119	250.5	369.5	10,527	3.5 %
CM Permian/202	25.7	76.7	102.4	4,767	2.2 %
CM Permian/summer 2021	28.0	65.5	93.5	5,950	1.6 %
CM Permian/fall 2021	28.0	65.4	93.4	6,228	1.5 %
CM Permian F2021, boundary/2019	54.2	92.7	146.9	4,756	3.1 %
CM Permian F2021, Delaware/2019	30.7	50.6	81.3	3,613	2.3 %
CM Permian F2021, Midland/2019	23.8	42.4	66.2	1,143	5.8 %
Total			**1,080.9**	**38,936**	**2.8 %** [d]

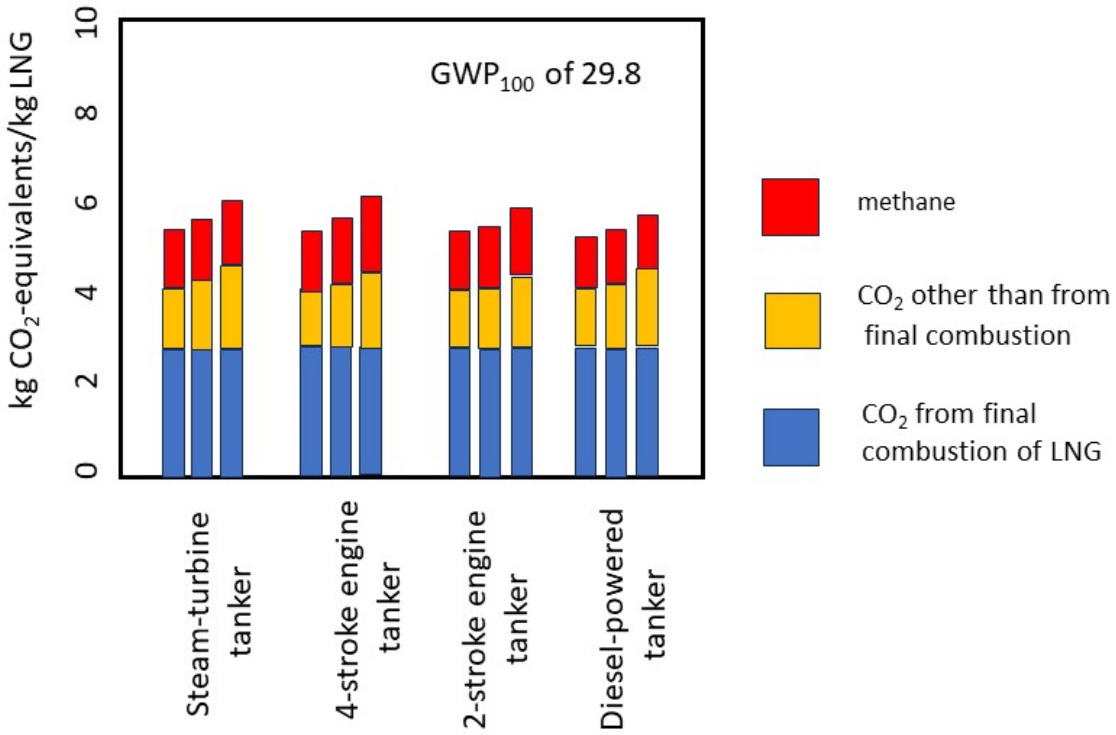
a) Calculated from data in Table S10, Table S12, and Table S24 of supplemental material from Sherwin et al. (2024), with emissions weighted for natural gas vs oil considering energy basis.
b) Calculated from data in Table S10 and Table S12 of supplemental material from Sherwin et al. (2024).
c) From Table S10 of supplemental material from Sherwin et al. (2024)
d) Percent of production emitted as methane weighted by the production occurring during each campaign.

Supplemental Table B. Full lifecycle greenhouse gas emissions for LNG for 4 different tanker-transport scenarios, using shortest voyages (21.4 days round-trip). Methane emissions are shown both as mass of methane and mass of CO_2 equivalents based on GWO_{20}. Values are per final mass of LNG consumed. Numbers in parentheses indicate the percent for each component of the total CO_2 equivalents.

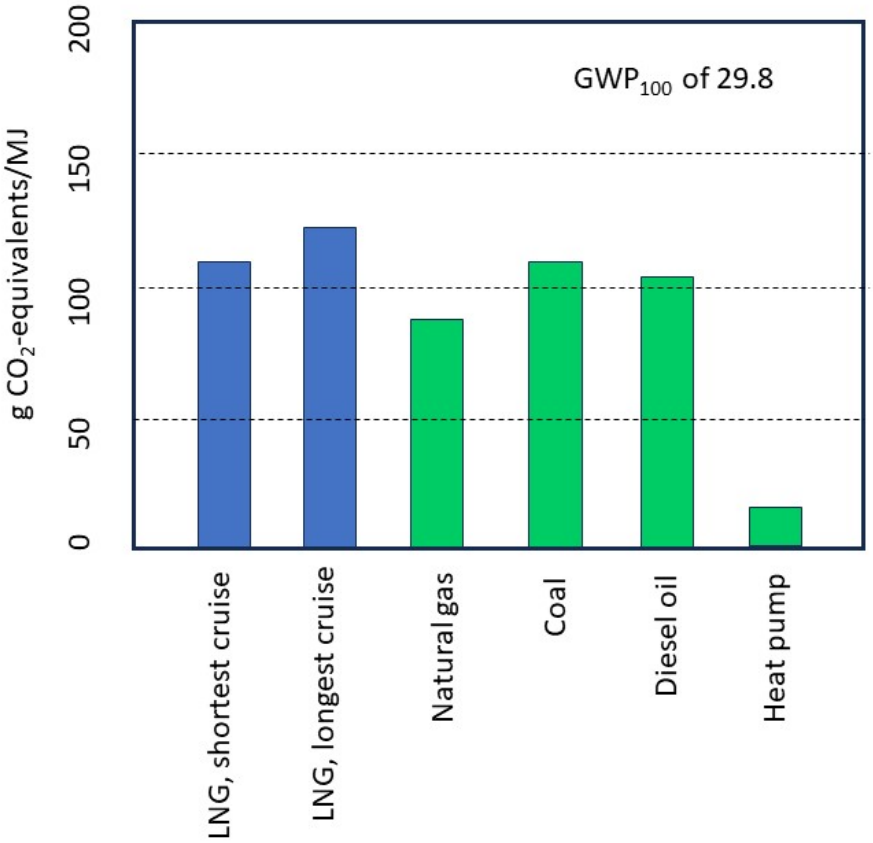
	Carbon Dioxide	Methane		Total combined
	g CO_2/kg	g CH_4/kg	g CO_2-eq/kg	g CO_2-eq/kg
Steam-turbine tankers powered by LNG				
Upstream & midstream emissions	735 (9.9%)	34.6	2,854 (38%)	3,589 (48%)
Liquefaction	366 (4.9%)	3.7	306 (4.1%)	673 (9.0%)
Emissions from tanker	169 (2.3%)	0	0 (0%)	169 (2.3%)
Final transmission & distribution	0 (0%)	3.2	264 (3.5%)	264 (3.5%)
Combustion by final consumer	2,750 (37%)	0	0 (0%)	2,750 (37%)
Total	**4,021** (54%)	**41.5**	**3,424** (46%)	**7,445**
4-stroke engine tankers powered by LNG				
Upstream & midstream emissions	727 (9.6%)	34.2	2,819 (37%)	3,545 (47%)
Liquefaction	362 (4.8%)	3.7	303 (4.0%)	665 (8.8%)
Emissions from tanker	126 (1.7%)	2.9	242 (3.2%)	367 (4.8%)
Final transmission & distribution	0 (0%)	3.2	264 (3.5%)	264 (3.5%)
Combustion by final consumer	2,750 (36%)	0	0 (0%)	2,750 (36%)
Total	**3,964** (52%)	**44.0**	**3,627** (48%)	**7,591**
2-stroke engine tankers powered by LNG				
Upstream & midstream emissions	720 (9.7%)	33.9	2,794 (38%)	3,514 (47%)
Liquefaction	359 (4.8%)	3.6	300 (4.0%)	659 (8.8%)
Emissions from tanker	104 (1.4%)	1.4	119 (1.6%)	224 (3.0%)
Final transmission & distribution	0 (0%)	3.2	264 (3.6%)	264 (3.6%)
Combustion by final consumer	2,750 (37%)	0	0 (0%)	2,750 (37%)
Total	**3,933** (53%)	**42.2**	**3,478** (47%)	**7,411**
Diesel-powered tankers				
Upstream & midstream emissions	693 (9.6%)	32.6	2,689 (37%)	3,381 (47%)
Liquefaction	345 (4.8%)	3.5	289 (4.0%)	634 (8.8%)
Emissions from tanker	183 (2.5%)	0.1	8.3 (0.1%)	192 (2.6%)
Final transmission & distribution	0 (0%)	3.2	264 (3.7%)	264 (3.7%)
Combustion by final consumer	2,750 (38%)	0	0 (0%)	2,750 (38%)
Total	**3,971** (55%)	**39.4**	**3,250** (45%)	**7,221**

Supplemental Table C. Full lifecycle greenhouse gas emissions for LNG for 4 different tanker-transport scenarios, using longest voyages (70 days round-trip). Methane emissions are shown both as mass of methane and mass of CO_2 equivalents based on GWO_{20}. Values are per final mass of LNG consumed. Numbers in parentheses indicate the percent for each component of the total CO_2 equivalents.

	Carbon Dioxide	Methane		Total combined
	g CO_2/kg	g CH_4/kg	g CO_2-eq/kg	g CO_2-eq/kg
Steam-turbine tankers powered by LNG				
Upstream & midstream emissions	833 (9.9%)	39.1	3,229 (38%)	4,061 (48%)
Liquefaction	415 (4.9%)	4.2	347 (4.1%)	761 (9.0%)
Emissions from tanker	554 (6.6%)	0	0 (0%)	554 (6.6%)
Final transmission & distribution	0 (0%)	3.2	264 (3.1%)	264 (3.1%)
Combustion by final consumer	2,750 (33%)	0	0 (0%)	2,750 (33%)
Total	**4,551** (54%)	**46.5**	**3,839** (46%)	**8,390**
4-stroke engine tankers powered by LNG				
Upstream & midstream emissions	803 (9.1%)	37.8	3,115 (35%)	3,918 (44%)
Liquefaction	400 (4.5%)	4.1	335 (3.8%)	735 (8.3%)
Emissions from tanker	412 (4.6%)	9.6	790 (8.9%)	1,202 (14%)
Final transmission & distribution	0 (0%)	3.2	264 (3.0%)	264 (3.0%)
Combustion by final consumer	2,750 (31%)	0	0 (0%)	2,750 (31%)
Total	**4,364** (49%)	**54.5**	**4,504** (51%)	**8,869**
2-stroke engine tankers powered by LNG				
Upstream & midstream emissions	782 (9.4%)	36.8	3,035 (37%)	3,817 (46%)
Liquefaction	390 (4.7%)	4.0	326 (3.9%)	716 (8.7%)
Emissions from tanker	342 (4.1%)	4.7	390 (4.7%)	732 (8.8%)
Final transmission & distribution	0 (0%)	3.2	264 (3.2%)	264 (3.2%)
Combustion by final consumer	2,750 (33%)	0	0 (0%)	2,750 (33%)
Total	**4,264** (52%)	**48.7**	**4,014** (48%)	**8,277**
Diesel-powered tankers				
Upstream & midstream emissions	693 (9.1%)	32.6	2,689 (35%)	3,381 (44%)
Liquefaction	345 (4.5%)	3.5	289 (3.8%)	634 (8.3%)
Emissions from tanker	600 (7.8%)	0.3	27 (0.4%)	627 (8.2%)
Final transmission & distribution	0 (0%)	3.2	264 (3.4%)	264 (3.4%)
Combustion by final consumer	2,750 (36%)	0	0 (0%)	2,750 (36%)
Total	**4,388** (57%)	**39.6**	**3,269** (43%)	**7,656**



Supplemental Figure A. Full lifecycle greenhouse gas footprints for LNG expressed per mass of LNG burned by final consumer, comparing four scenarios where the LNG is transported by different types of tankers. For each type of tanker, scenarios are shown for shortest voyage times (bars to the left), average voyage times (center bars), and longest voyage times (bars to the right). Emissions of methane, the carbon dioxide emitted from the final combustion, and other carbon dioxide emissions are shown separately. Methane emissions are converted to carbon dioxide equivalents using GWP_{100}. This figure is identical to Figure 2, except for converting methane emissions using GWP_{100} rather than GWP_{20}.



Supplemental Figure B. Full lifecycle greenhouse gas footprint for LNG for both short and long cruises compared to coal used domestically, diesel oil used domestically, natural gas used domestically, and electric-power ground source heat pump powered by the average European electric grid. The LNG values are the means for the three types of tankers that burn LNG for fuel. Methane emissions are converted to carbon dioxide equivalents using GWP_{100}. This figure is identical to Figure 2, except for converting methane emissions using GWP_{100} rather than GWP_{20}. Note that values are expressed per unit of heat energy for each fuel for delivery to an electric generation plant. This does not include methane emissions from urban distribution systems that deliver to buildings for heat. Emissions for LNG and natural gas used domestically would both increase substantially for this use of gas.