**Supplementary Information File 1.**

**For**

**How Sustainable is Liquefied Natural Gas Supply Chain? An Integrated Life Cycle Sustainability Assessment Model**

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1. Cumulative sustainability assessment detailed results:

The results in Tables 4, 5, and 6 show each stage's negative and positive impacts in the LNG process chain, the contribution of each stage, and the final scoring. The cumulative sustainability assessment methodology was followed, and the following are the main results.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Units | Natural gas extraction | Pre-separation unit | MDEA Sweetening unit | SRU and TGTU units | Dewatering unit | NGL recovery and fractionation units | Liquefaction unit | LNG loading (export terminal) | LNG shipping | LNG receiving terminal |
| *Environmental indicators (negative indicators)* | | | | | | | | | | | |
| Global Warming Potential | kg CO2-eq. | 53,648,395.34 | 3,630,834.41 | 25,414,306,084.39 | 569,820,482.48 | 9,591,964,940.34 | 65,316,380.97 | 21,012,275,442.69 | 42,201,635,518.84 | 742,164,478.68 | 4,933,090,400.29 |
| Particulate Matter Formation Potential | kg PM2.5-eq. | 7,740.91 | 1,308,947.10 | 67,015,269.55 | 1,483,250,846.87 | 40,551,701.60 | 33,094.41 | 79,849,788.70 | 177,395,647.88 | 925,655.30 | 20,803,647.24 |
| Photochemical Oxidant Formation Potential | kg NOx-eq. | 78,932.64 | 14,129.75 | 367,511,207.61 | 50,239,730.24 | 226,246,569.61 | 118,701.79 | 469,812,499.27 | 1,043,728,533.51 | 1,522,491.68 | 122,400,674.00 |
| Energy Consumption | TJ | 2,838.52 | 0.02 | 0.05 | 0.00 | 0.02 | 107.49 | 0.06 | 0.17 | 0.17 | 0.17 |
| Land Used | Km2 | 1.93 | 0.08 | 0.47 | 0.46 | 0.03 | 7.37 | 5.38 | 18.50 | 1,390.20 | 8.20 |
| The Use of Water | m3 | 0.10 | 2,933,491.53 | 11,842,116,930.54 | 1,046,177,060.68 | 7,489,438.16 | 3,195,927,235.24 | 0.00 | 0.00 | 1,306,193.88 | 0.00 |
| Removal of water | m3 | 0.42 | 1,257,210.66 | 5,075,192,970.23 | 448,361,597.43 | 3,209,759.21 | 1,369,683,100.82 | 0.00 | 0.00 | 870,795.92 | 3,354,545.97 |
| *Social indicators (positive indicators)* | | | | | | | | | | | |
| Employment | person | 2,329.48 | 262.00 | 88.00 | 175.00 | 175.00 | 524.00 | 88.00 | 88.00 | 216.70 | 88.00 |
| Compensation of employment | USD | 2,875,972.32 | 2,871,232.88 | 964,383.56 | 1,917,808.22 | 964,383.56 | 5,742,465.75 | 964,383.56 | 964,383.56 | 26,004,221.13 | 964,383.56 |
| Total Tax | USD | 1,859,175.01 | 7,297,074.47 | 6,193,032,165.03 | 2,731,463,859.54 | 41,522,207.00 | 3,917,033,188.99 | 529,534,366.83 | 4,649,571,342.77 | 1,178,042,556.48 | 233,942,880.48 |
| Man Hours | hrs | 4,774,176.64 | 568,632.00 | 198,120.00 | 377,496.00 | 222,144.00 | 1,130,040.00 | 212,568.00 | 464,400.00 | 780,126.63 | 88.00 |
| *Social indicators (negative indicators)* | | | | | | | | | | | |
| Human Health | DALY | 54.73 | 826.71 | 66,071.52 | 933,539.29 | 34,614.25 | 81.54 | 70,152.44 | 151,694.77 | 835.68 | 17,774.79 |
| *Economic indicators (positive indicators)* | | | | | | | | | | | |
| Gross Operating Surplus | USD | 41,865,062,658.20 | 72,970,744.73 | 61,930,321,650.33 | 27,314,638,595.40 | 415,222,070.00 | 39,170,331,889.94 | 5,295,343,668.33 | 46,495,713,427.72 | 11,780,425,564.78 | 2,339,428,804.76 |
| Salvage value (End of life) | USD | 6,556,063,549.40 | 5,705,827.07 | 1,016,908,617.63 | 1,163,670,729.50 | 1,483,983.39 | 1,734,728,535.17 | 610,557,120.08 | 852,238.00 | 386,967,576.32 | 949,242.00 |
| *Economic indicators (negative indicators)* | | | | | | | | | | | |
| Operational Cost | USD | 10,584,000.00 | 3,546,411.99 | 6,937,933,632.82 | 2,325,693,306.95 | 20,020,317.22 | 3,394,922,207.94 | 55,597,005.62 | 508,846,930.00 | 2,355,957,653.32 | 33,647,280.00 |
| Equipment Cost | USD | 26,224,254,197.58 | 28,529,135.36 | 5,084,543,088.13 | 5,818,353,647.50 | 163,115,540.32 | 8,052,653,996.44 | 3,052,785,600.38 | 26,704,261,190.00 | 1,547,870,305.30 | 1,304,448,960.00 |

**Table 1.** Negative and positive LCA, LCC, and SLCA results related to the LNG process chain.

**Table 2.** Contribution (%) of each LCI among the others throughout the LNG process chain.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Natural gas extraction | Pre-separation unit | MDEA Sweetening unit | SRU and TGTU units | Dewatering unit | NGL recovery and fractionation units | Liquefaction unit | LNG loading (export terminal) | LNG shipping | LNG receiving terminal |
| *Environmental indicators (negative indicators)* | | | | | | | | | | |
| Global Warming Potential | 0% | 0% | 60% | 1% | 23% | 0% | 50% | 100% | 2% | 12% |
| Particulate Matter Formation Potential | 0% | 0% | 5% | 100% | 3% | 0% | 5% | 12% | 0% | 1% |
| Photochemical Oxidant Formation Potential | 0% | 0% | 35% | 5% | 22% | 0% | 45% | 100% | 0% | 12% |
| Energy Consumption | 100% | 0% | 0% | 0% | 0% | 4% | 0% | 0% | 0% | 0% |
| Land Used | 0% | 0% | 0% | 0% | 0% | 1% | 0% | 1% | 100% | 1% |
| The Use of Water | 0% | 0% | 100% | 9% | 0% | 27% | 0% | 0% | 0% | 0% |
| Removal of water | 0% | 0% | 100% | 9% | 0% | 27% | 0% | 0% | 0% | 0% |
| *Social indicators (positive indicators)* | | | | | | | | | | |
| Employment | 100% | 11% | 4% | 8% | 8% | 22% | 4% | 4% | 9% | 4% |
| Compensation of employment | 11% | 11% | 4% | 7% | 4% | 22% | 4% | 4% | 100% | 4% |
| Total Tax | 0% | 0% | 100% | 44% | 1% | 63% | 9% | 75% | 19% | 4% |
| Man Hours | 100% | 12% | 4% | 8% | 5% | 24% | 4% | 10% | 16% | 0% |
| *Social indicators (negative indicators)* | | | | | | | | | | |
| Human Health | 0% | 0% | 7% | 100% | 4% | 0% | 8% | 16% | 0% | 2% |
| *Economic indicators (positive indicators)* | | | | | | | | | | |
| Gross Operating Surplus | 68% | 0% | 100% | 44% | 1% | 63% | 9% | 75% | 19% | 4% |
| Salvage value (End of life) | 100% | 0% | 16% | 18% | 0% | 26% | 9% | 0% | 6% | 0% |
| *Economic indicators (negative indicators)* | | | | | | | | | | |
| Operational Cost | 0% | 0% | 100% | 34% | 0% | 49% | 1% | 7% | 34% | 0% |
| Equipment Cost | 98% | 0% | 19% | 22% | 1% | 30% | 11% | 100% | 6% | 5% |

**Table 3.** Scoring of each LCI.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Natural gas extraction | Pre-separation unit | MDEA Sweetening unit | SRU and TGTU units | Dewatering unit | NGL recovery and fractionation units | Liquefaction unit | LNG loading (export terminal) | LNG shipping | LNG receiving terminal |
| *Environmental indicators (negative indicators)* | | | | | | | | | | |
| Global Warming Potential | 5 | 5 | 2 | 5 | 4 | 5 | 3 | 1 | 5 | 5 |
| Particulate Matter Formation Potential | 5 | 5 | 5 | 1 | 5 | 5 | 5 | 5 | 5 | 5 |
| Photochemical Oxidant Formation Potential | 5 | 5 | 4 | 5 | 4 | 5 | 3 | 1 | 5 | 5 |
| Energy Consumption | 1 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Land Used | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 1 | 5 |
| The Use of Water | 5 | 5 | 1 | 5 | 5 | 4 | 5 | 5 | 5 | 5 |
| Removal of water | 5 | 5 | 1 | 5 | 5 | 4 | 5 | 5 | 5 | 5 |
| Total score | **31** | **35** | **23** | **31** | **33** | **33** | **31** | **27** | **31** | **35** |
| *Social indicators (positive indicators)* | | | | | | | | | | |
| Employment | 5 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 |
| Compensation of employment | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 5 | 1 |
| Total Tax | 1 | 1 | 5 | 3 | 1 | 4 | 1 | 4 | 1 | 1 |
| Man Hours | 5 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 |
| *Social indicators (negative indicators)* | | | | | | | | | | |
| Human Health | 5 | 5 | 5 | 1 | 5 | 5 | 5 | 5 | 5 | 5 |
| Total score | **17** | **9** | **13** | **7** | **9** | **15** | **9** | **12** | **13** | **9** |
| *Economic indicators (positive indicators)* | | | | | | | | | | |
| Gross Operating Surplus | 4 | 1 | 5 | 3 | 1 | 4 | 1 | 4 | 1 | 1 |
| Salvage value (End of life) | 5 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 |
| *Economic indicators (negative indicators)* | | | | | | | | | | |
| Operational Cost | 5 | 5 | 1 | 4 | 5 | 3 | 5 | 5 | 4 | 5 |
| Equipment Cost | 1 | 5 | 5 | 4 | 5 | 4 | 5 | 1 | 5 | 5 |
| Total score | **15** | **12** | **12** | **12** | **12** | **13** | **12** | **11** | **11** | **12** |