Energy efficiency and CO$_2$ emissions in LNG chains

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Typical distribution of CO$_2$ emissions

Relative CO$_2$ emissions: 50-80%

- Power & Heat Feed Gas
- Propulsion
- Pumping Regas

Production
Processing & Liquefaction
Shipping
Receiving
End-use

80-90%
Efficiency in power generation

Relative CO₂ emissions

- GE Frame 5
- GE Frame 6
- GE Frame 7
- Coberra 6761
- GE LM2500+
- GE LM6000
- RR Trent 800
- Combined cycle

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
## Efficiency in ship propulsion

<table>
<thead>
<tr>
<th>Type</th>
<th>NO\textsubscript{x} (g/kWh)</th>
<th>SO\textsubscript{x} (g/kWh)</th>
<th>Particulates (g/kWh)</th>
<th>CO\textsubscript{2} (g/kWh)</th>
<th>Relative CO\textsubscript{2} emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low speed diesel</td>
<td>17</td>
<td>12.9</td>
<td>0.5</td>
<td>580</td>
<td>0.0</td>
</tr>
<tr>
<td>Medium speed diesel</td>
<td>12</td>
<td>13.6</td>
<td>0.4</td>
<td>612</td>
<td>0.2</td>
</tr>
<tr>
<td>Dual fuel diesel electric</td>
<td>1.3</td>
<td>0.05</td>
<td>0.05</td>
<td>420</td>
<td>0.4</td>
</tr>
<tr>
<td>Steam turbine</td>
<td>1</td>
<td>11.0</td>
<td>2.5</td>
<td>850*</td>
<td>0.6</td>
</tr>
<tr>
<td>Gas turbine</td>
<td>2.5</td>
<td>0</td>
<td>0.01</td>
<td>480</td>
<td>0.8</td>
</tr>
</tbody>
</table>

*using 50% boil-off gas and 50% heavy fuel oil for steam generation

Estimated CO$_2$ emissions from different LNG chains

*Combined cycle power generation applied for Shtokman case
CO₂ reduction stair

BaseCase
- Warm climate
- 10% CO₂
- No CO₂ deposition
- Frame7 GT
- No WHRU
- Gas exp. process
- Air cooling
- Steam propulsion
- 5000 km LNG transport
- SCV (gas fired)
CO$_2$ reducing measures & potentials

AnSu
ASU
Heatpump
NGL process
Opt.energy plant
Dual fuel
Cryopower
Heat integration
NGL process
CCS
El.from grid*

*renewable energy, **@ el.from grid
Towards "zero emission LNG chain"

- Plant efficiency
- Renewable power, CCS
- Renewable heat (Oxyfuel heat)
- CO₂ disposal from feed gas
- Effective propulsion systems
- Short distance transportation
- Efficient cold utilization

Production | Processing & Liquefaction | Shipping | Receiving | End-use
Case study – LNG vs PIPELINE
Applied tools: SCEET-LNG & SCEET-PIPELINE

Hammerfest-Europe, 2500 km

- NG feed 20 mill Sm³/d (≈4.3 mtpa LNG)
- CO₂ disposal for LNG (Removal to 50 ppm for LNG and 2.5% for PIPELINE)
- LNG Case (Calculations with SCEET-LNG)
  - Hydropower, Gas fired heaters, Dual fuel ship propulsion, SW regas
- PIPELINE Case (Calculations with SCEET-PIPELINE)
  - Hammerfest-Norne (800 km, Hydropower)
  - Norne-Kårstø (700 km, Gas turbine power)
  - Kårstø-Europe (1000 km, Hydropower)
Case study – LNG vs PIPELINE
Hammerfest-Europe, 2500 km

PIPELINE Case

<table>
<thead>
<tr>
<th>Component</th>
<th>CO2/kg/ton gas delivered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-treat</td>
<td>20,8</td>
</tr>
<tr>
<td>CO2 from feed</td>
<td>73,4</td>
</tr>
<tr>
<td>Comp1 + NGL</td>
<td>1,6</td>
</tr>
<tr>
<td>Comp2</td>
<td>18,2</td>
</tr>
<tr>
<td>Comp3</td>
<td>0,0</td>
</tr>
<tr>
<td>Total</td>
<td>114</td>
</tr>
</tbody>
</table>

LNG Case

<table>
<thead>
<tr>
<th>Component</th>
<th>CO2/kg/ton LNG delivered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-treat</td>
<td>42,6</td>
</tr>
<tr>
<td>CO2 from feed</td>
<td>0,0</td>
</tr>
<tr>
<td>Upstream</td>
<td>12,1</td>
</tr>
<tr>
<td>Transport</td>
<td>23,2</td>
</tr>
<tr>
<td>Regas</td>
<td>3,1</td>
</tr>
<tr>
<td>Total</td>
<td>81</td>
</tr>
</tbody>
</table>
Summary & Conclusions

• It is possible to reduce CO$_2$ emission from all parts of the LNG chain by using best available technology
• Efficient power and heat generation is necessary to lower CO$_2$ emissions
• Efficient propulsion for transportation is an important factor to reduce CO$_2$ emissions
• Use of LNG cold at the receiving terminal for cryogenic cooling/processes has significant potential regarding reduction of CO$_2$ emissions
• The “near zero emissions LNG” is possible if renewable energy is used for the liquefaction plant in combination with efficient ship propulsion and LNG cold utilization
• In a global perspective the best solution may be to use natural gas in an optimal way at the production site to produce power & heat
Thank you!

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