LNG Terminal Risk Assessment

LNG Shipping Symposium

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Risks

- Accident with LNG
- Sea - to - road
- Access to capital
- OPEX
- Security of supply
- More regulations
- CAPEX
- Short-term financial expectation

Opportunities

- 1st mover advantage
- Technology leadership
- Societal wealth
- OPEX
- Brand
- Alliances
- Business model
- Commercial niches
Small Import Terminal
Discharge of gas ongoing
use bus-stop on other side of quai
small scale LNG in the big picture

Perspectives & roles
- Policy makers
- Governments
- Port authorities
- Ship owners
- LNG bunker suppliers
- O&G Majors

Developments
- Regulations
- Infrastructure
- Business
- Port permitting processes
- Technologies

Today’s infrastructure development

Tomorrow’s infrastructure

Tomorrow’s markets

Import & large scale storage
Intermediate distribution
Intermediate storage
Bunker / Break Bulk
Marine fuel / other markets
Enablers for LNG bunkering to develop in ports

- LNG availability, for example the nearby presence of an import terminal
- Reliable & safe logistical concepts
- Legal certainty, established legislation and regulatory framework
- Favorable investment climate & taxation regime
- Necessary competences, knowledge & skills
- Public acceptance
More than 50 years of technology development

Historical LNG trade

- Membrane tank developed and tested
- Moss Spherical tank design
- Rules for barg mounted LNG plant
- Spadeadam test facility
- Standard for offshore concrete structures for LNG
- “Oil crises”
- “Kyoto”
- Guidelines and criteria for floating LNG FPSO and terminals
- Frist Classification contract for FSRU
- Classification contract for FLNG
- Onshore Service Spec for LNG facilities
- Oil supply concerns
- Published rules for gas carriers
- Research team on LNG established
- Classification contract for “mega” LNG carriers
- First Classification contract for FSRU

10E9 cubic meter


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LNG distribution needs to take a step
Decision support framework for major accident risk management

Significance to Decision Making Progress

MEANS OF CALIBRATION

Codes and Standards
Verification
Per Review
Benchmarking
Internal Stakeholder Consultation
External Stakeholder Consultation

DECISION CONTEXT TYPE

Nothing new or unusual
Well understood risks
Established practice
No major stakeholder implications

Lifecycle implications
Some risk trade-offs/transfers

Some uncertainty or deviation from standard or best practice
Significant economic implications

Very novel or challenging
Strong stakeholder views and perceptions

Significant risk trade-offs or risk transfer
Large uncertainties
Perceived lowering of safety standards

Source: OGP draft 116901
Risk assessment – no rocket science

- Risk Identification
- Risk Assessment
- Risk Response Planning
ISO 31000 Risk management process

Communication and consultation

Establishing the context
- Safety
- Environment
- Business

Monitoring and review
- Risk identification
- Risk analysis
- Risk evaluation
- Risk treatment

Risk assessment
RP: Structure for introducing barriers

1st layer of defence
Barriers to prevent release

2nd layer of defence
Barriers to contain release

3rd layer of defence
Barriers to minimize consequences

Release of LNG or NG

Cause 1
Cause 2
Cause 3
Cause ...

Consequence 1
Consequence 2
Consequence ...

3rd layer of defence - Minimize consequences
The RP: overall process description

Planning, design and operation of LNG bunkering facilities

- Design of hardware (1st LOD)
- Instrumentation and control (1st LOD)
- Design of operational procedures (1st LOD)
- Design of hardware and systems (2nd LOD)
- Emergency response plan (3rd LOD)
- Use of operational procedures (1st LOD)

Safety management

- Establish safety philosophy and targets
- Agree upon organisation
- Secure proper training of personnel
- Implement organisation and procedures

Risk assessment

- High level risk assessment for site location
- Use the risk assessment as input to design
- Determine the safety zone
- Determine the security zone
- Demonstrate acceptance of the facility
- Perform a safe job analysis, new ships, etc.

Authority
Supplier
Receiving Ship
### (some) possible LNG release scenarios

<table>
<thead>
<tr>
<th>Source of release</th>
<th>Scenario</th>
<th>Possible causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>General process and cargo handling</td>
<td>Accidental release from equipment and piping</td>
<td>Lack of flange tightness</td>
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<tr>
<td></td>
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<td>Weld defects</td>
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<tr>
<td></td>
<td></td>
<td>Corrosion</td>
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<tr>
<td></td>
<td></td>
<td>Impact</td>
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<tr>
<td></td>
<td></td>
<td>Supporting structure damage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Earthquake, floods and other natural hazards</td>
</tr>
<tr>
<td>Accidental release from LNG tanks</td>
<td>Ship collision</td>
<td>Passing ship adrift</td>
</tr>
<tr>
<td>tanks at jetty or on ships</td>
<td>Ship pressure relief valve</td>
<td>Overpressure</td>
</tr>
<tr>
<td>Onshore storage</td>
<td>Tank leakage</td>
<td><strong>Internal or external leak in tank bottom or wall</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Catastrophic rupture and leakages</strong></td>
</tr>
<tr>
<td></td>
<td>Tank PSV release</td>
<td>Tank overfilling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tank overpressure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rollover</td>
</tr>
</tbody>
</table>
Risk - Identification: example Rollover

- Evaporation
- Evaporation at reduced rate
- Flushing Overpressure

Convection cell

- Convection cell
- heavy
- light
Risk – Analysis: example spill scenario
Risk – Analysis: example Simplified event tree

Source: OGP draft 116901
Risk – Assessment: example FN-curves – group risk, societal risk

IMO MSC 83/21/1

Risk level - LNG carriers

Group
24 / 365
Cumulative
Timeline of typical project – activities in first phase

- Strategy
- Feasibility
- Concept development
- Seveso II process
- Design
- Construction
- Commissioning
- Operation

Filing Seveso application
Risk assessment integrated in overall process

Strategy
- Market outlook
- Demand estimate
- Supply volumes & frequencies
- Storage volumes
- Bunker volumes & frequencies
- Logistics concept
- Bunker modes

Feasibility
- Showstopper analysis
- Feasibility analysis
- Initial HAZID
- Initial nautical QRA
- Initial site QRA

Concept development
- Development of initial LNG bunkering procedures
- Development of ship concept (LNG Carrier link to (re)export terminal)
- Development of bunker vessel concept
- Management of permit application
- Development of organisational / company setup (make) or requirements on supplier (buy)

Project management office
- Project risk management
Risk pictures in Port for / from elements of LNG value chain
## Tools in place

<table>
<thead>
<tr>
<th>Operation</th>
<th>Commissioning</th>
<th>Construction</th>
<th>Design</th>
<th>Feasibility</th>
<th>Strategy</th>
</tr>
</thead>
</table>

**Rules for Classification of Ships**

**Recommended Practice**

*Development and operation of liquefied natural gas bunkering facilities*

Guidance on performing risk assessment in the design of onshore LNG installations including the ship/shore interface.

- **Import & large scale storage**
- **Intermediate distribution**
- **Intermediate storage**
- **Bunker / Break Bulk**
- **Marine fuel / other markets**
Managing project risks – keep schedule and budget on track

- Decisions made
- Cost fixed
- Money spent
- Degree of freedom to make changes

Keep budget
Stay in schedule

100%

strategy feasibility design construction Commissioning operation
State of the art – hard arms (Marine Loading Arms)
Loading arm – quick connect / disconnect
Loading arm – Emergency Release Coupling
Hoses
... the RP suggests how to work with them
Operation & design: 1st layer of defence

- Equipment standard, inspection and testing
- Operational planning
- Compatibility of the transfer systems
- Pre-transfer operations
- Transfer hoses
- Couplings
- Emergency Release System, ERS
- Loading arms
- Inerting/purging operations
- Transfer operations

- Transfer stop
- **Trapped LNG**
- Vent mast
- **Draining/stripping operations**
- Disconnection of the systems
- Quantity and properties of the supplied LNG (pressure / temperature)
Operation & design: 2\textsuperscript{nd} layer of defence

- Ignition prevention
- Emergency shut-down system
- Prevention against electrostatic and galvanic ignition
- Leakage detection
- Cryogenic spill protection
- PPE
- Fire protection and suppression
- Operation inside the safety zone
SMS: 3rd layer of defence – Emergency Management

- Rescuing casualties,
- Safeguarding / evacuating others,
- Minimising damage to property and the environment,
- Preventing escalation / bringing the incident under control.

Practical and location- and/or situation-specific emergency procedures and exercises.
<table>
<thead>
<tr>
<th>Barriers</th>
<th>High risk hazards</th>
<th>Medium risk hazards with potential fatalities</th>
<th>Other medium risk hazards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of barriers from threat to consequence</td>
<td>5 controls + recovery measures</td>
<td>4 controls + recovery measures</td>
<td>3 controls + recovery measures</td>
</tr>
<tr>
<td>Controls (threat)</td>
<td>3 controls to be in place for each identified threat. Alternative: 4 controls</td>
<td>2 controls to be in place for each identified threat. Alternative: 3 controls</td>
<td>2 controls to be in place for each identified threat</td>
</tr>
<tr>
<td>Recovery measures (consequence)</td>
<td>2 recovery measures required for each identified consequence. Alternative: 1 recovery measure</td>
<td>2 recovery measures required for each identified consequence. Alternative: 1 recovery measure</td>
<td>1 recovery measure required for each identified consequence</td>
</tr>
</tbody>
</table>

Source: OGP draft 116901
### Risk Matrix – asset owner

<table>
<thead>
<tr>
<th>Area of assessment</th>
<th>Specific sector of activity at global level</th>
<th>Specific sector of activity in Repsol YPF</th>
<th>Area of assessment according to the area of business activity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unheard of</td>
<td>It has not happened</td>
<td>It has happened before</td>
</tr>
<tr>
<td></td>
<td></td>
<td>It has happened before</td>
<td>It has happened in the last five years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>It happens on an annual basis</td>
<td>It happens on a monthly basis</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Consequences

<table>
<thead>
<tr>
<th>Level of consequences</th>
<th>Personal injury</th>
<th>Damage to property and loss of profits, Environmental remediation costs</th>
<th>Environmental damage</th>
<th>Level of diffusion; reputation</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Incidents not causing injury or leave</td>
<td>5K - 10K</td>
<td>Environmental incident in an area without grossly committed crime or damage within the limits of the property</td>
<td>No diffusion</td>
<td>1.7</td>
</tr>
<tr>
<td>Moderate</td>
<td>Up to 30 days of injury leave ≤ 1% probability of death</td>
<td>100K - 1M</td>
<td>Relevant environmental damage that exceeds the levels of reference for environmental quality and is capable of generating legal action and does not have permanent effects</td>
<td>Green Level Crisis</td>
<td>3</td>
</tr>
<tr>
<td>Serious</td>
<td>More than 30 days of injury leave &gt; 1% probability of death</td>
<td>1M - 10M</td>
<td>Serious environmental damage that could affect the property's environment, which exceeds the reference levels for environmental quality and could affect third parties</td>
<td>Yellow Level Crisis</td>
<td>7</td>
</tr>
<tr>
<td>Very serious</td>
<td>Could cause a death or permanent injuries</td>
<td>10M - 100M</td>
<td>Very serious environmental damage. The company is required to provide significant correction and/or compensation measure; in large areas exceeds the reference levels for environmental quality, high probability of permanent residual damage</td>
<td>Red Level Crisis</td>
<td>16</td>
</tr>
<tr>
<td>Disastrous</td>
<td>Could cause between 2 and 9 deaths</td>
<td>100M - 1000M</td>
<td>Catastrophic environmental damage, loss of environmental resources and services. Permanent damage</td>
<td>Temporary international allocation</td>
<td>10</td>
</tr>
<tr>
<td>Catastrophic</td>
<td>Could cause 9 deaths or more</td>
<td>&gt; 1000M</td>
<td>Catastrophic and widespread environmental damage, extensive loss of environmental resources and services. Permanent damage</td>
<td>Permanent international allocation</td>
<td>100</td>
</tr>
</tbody>
</table>
Opportunities in an emerging industry

VALUE CHAIN

- Strategy
- Feasibility
- Design
- Construction
- Commissioning
- Operation

- Full scale import and storage
- Intermediate distribution
- Intermediate storage
- Bunker / break bulk
- Marine fuel / other markets

- First-mover advantage
- Technology leadership
- Business model
- Improved local environment
- Brand
- Alliances
- Diversified energy supply
- Societal wealth
Supply chain management

2014
Atmospheric -> Pressurized -> Pressurized
Atmospheric -> Atmospheric -> Pressurized

2016+
Atmospheric -> Pressurized -> Atmospheric
Atmospheric -> Atmospheric -> Atmospheric

Source: Liquefied Gas Handling Principles, SIGTTO
# small scale LNG in the big picture

<table>
<thead>
<tr>
<th>Operation</th>
<th>Tomorrow’s markets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commissioning</td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td></td>
</tr>
<tr>
<td>Design</td>
<td></td>
</tr>
<tr>
<td>Feasibility</td>
<td></td>
</tr>
<tr>
<td>Strategy</td>
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</tbody>
</table>

**Today’s infrastructure development**

- Import & large scale storage
- Intermediate distribution
- Intermediate storage
- Bunker / Break Bulk
- Marine fuel / other markets
### Netherlands

<table>
<thead>
<tr>
<th>ID/ Reference</th>
<th>Risk based</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Netherlands</strong></td>
<td><strong>Source: OGP</strong></td>
</tr>
<tr>
<td><strong>BEVI 2008, Besluit van 27 mei 2004, houdende milieukwaliteitseisen voor externe veiligheid van inrichtingen milieubeheer (Besluit externe veiligheid inrichtingen)</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Risk contour for land use planning**

- Vulnerable objects are divided in two classes. Legally binding endpoints apply.
- The first group accounts hospitals, schools, and residential areas; for these objects, a risk tolerability threshold of $10^{-6}$ event/year applies.
- The second group accounts less vulnerable objects as industrial zones, office buildings or recreational facilities. For these facilities, a tolerability threshold of $10^{-5}$ event/year applies.

**Societal**

- The definition of societal risk (SR) as the chance, for a number of people $>N$, to die as a direct consequence of their presence in the vicinity of a dangerous facility in which an accident occurs; non-binding tolerability endpoints apply.
- The acceptability criteria for an accident are 100 times stricter for every expected tenfold in number of victim (i.e. the acceptability of a disaster with 10 lethal victims is set on $10^{-5}$ event/year, for a disaster with 100 lethal victims $10^{-7}$ event/year, etc.).

**Other**

**Comments**

- QRA’s are performed using standard scenarios, consequence models and impact criteria. A computer program called SAFETI-NL with a tight limited degree of freedom is used to ensure consistent results.
### Japan

<table>
<thead>
<tr>
<th>Japan</th>
<th>Prescriptive</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID/ Reference</td>
<td>LNG terminal shall be designed and installed according to the designated laws and regulations. The designated laws and regulations are the nongovernmental guidance issued by the Japan Gas Association. The guidance is specific for LNG</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>Physical effects model give the relationships between the distance and effects. The further away the less the consequences. Therefore certain threshold values are set for the effect to decide on distance. The threshold values are set based on the extent of damages.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a) Radiation heat from pool fire</td>
</tr>
<tr>
<td></td>
<td>The level of damage by radiation heat is determined by the dose (combination of intensity and exposure time) a human body. For a long duration fire like a pool fire, the permissible limit of radiation is around 2,324 kJ/m²s (2,000 kcal/m²h).</td>
</tr>
<tr>
<td></td>
<td>b) Flash fire</td>
</tr>
<tr>
<td></td>
<td>Radiation effects from flash fires are, in view of the short duration, negligible. People caught in the flammable range, between ½ LFL and 2*LFL, will be affected.</td>
</tr>
<tr>
<td></td>
<td>c) Explosion</td>
</tr>
<tr>
<td>Comments</td>
<td>Suitable threshold values should be set before executing the risk assessment.</td>
</tr>
<tr>
<td></td>
<td>According to the Japanese High-Pressure Gas Safety Law and Safety Regulation for Plant Complex, the limit value of blast pressure for new installation is set to 9,800Pa (0.1 kgf/cm²) and a certain distance is to be secured</td>
</tr>
</tbody>
</table>

Source: OGP draft 116901
Germany

Major accident scenario

BImSchG
BImSchV
KAS 18
Large jetty / small carrier
Typical atmospheric tank design (Mitsubishi)
Cargo capacity: 1.100m³
Propulsion: 2 gas engines + 2 diesel engines
Mid Size Import Terminal
Pressure vessel (here: IMO type C)
Ship to Ship, “Other” to ship