

Rollover in LNG Storage Tanks

3rd Edition Update





INTERNATIONAL GROUP
OF LIQUEFIED NATURAL GAS IMPORTERS

Context

Rollover in LNG Storage Tanks

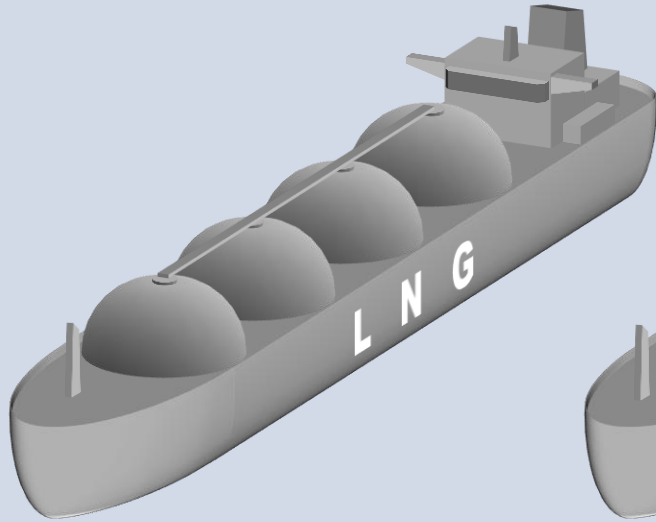
Summary Report by
the GIIGNL Technical
Study Group on the
Behaviour of
LNG in Storage



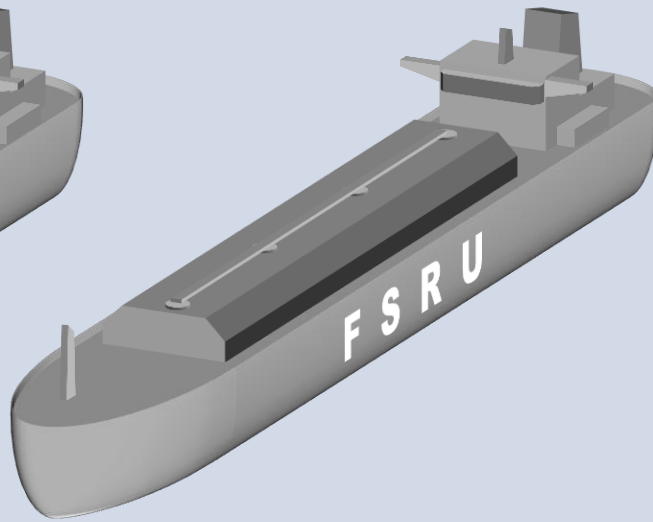
2nd Edition: 2012 - 2015 | Public Version



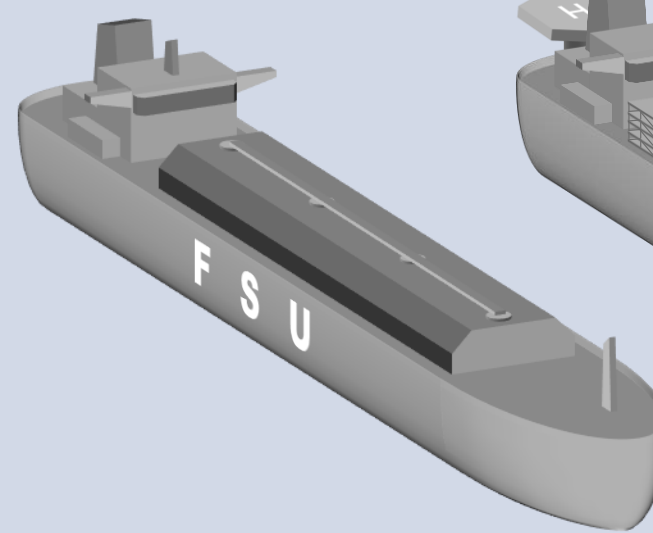
Scope



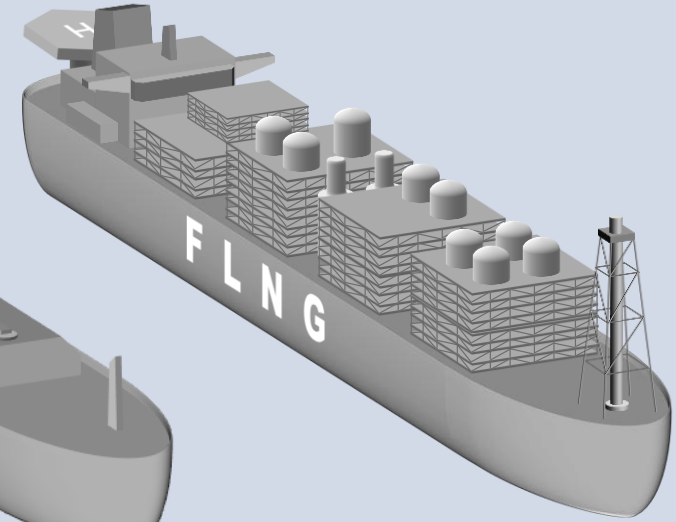
LNG Carriers



Floating
Storage and
Regasification
Units



Floating
Storage Units



Floating
Liquefaction
Facilities



Participants

#	Member	Company
1	Pablo Vega Perez (WG Lead)	Shell
2	Igor Rossi (Technical Coordinator)	Shell
3	Dave Robson	Shell
4	Abbas Mulji	MOL
5	Adrian Ruiz	SIGTTO
6	Carlos Guerrero	Bureau Veritas
7	Benoit Grovel	Bureau Veritas
8	Dhirendra Mishra	Shell (Hazira)
9	Richard Ellis	BP
10	Dineshsingh Pawar	BP
11	Eleni Lazaratou	Marangas
12	George Exarchopoulos	Marangas
13	Francois Ruggieri	GTT
14	Laurent Spittaël	GTT

#	Member	Company
15	Paul Emmanuel Decroes	Engie
16	Hugues Malvos	Engie
17	Remi Linotte	Engie
18	Jose Navarro	Lloyds Register
19	L M Van Der Werff	Gasunie
20	Lionel Martin	TotalEnergies
21	Roberto Vara	Freeport LNG
22	Nestor Aquino	Freeport LNG
23	Pradeep Kumar Bansal	TotalEnergies
24	Ümit Gürses	Egegaz
25	Vishal Chaudhary	Centrica
26	William Rincon	Spec LNG
27	Audrey Hubert	Engie
28	Tor Skogan	Moss Maritime



Framing

Brainstorming

Proposal 1

Proposal 2

Proposal 3

Proposal 4

Proposal 5

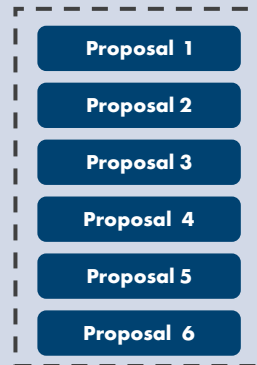
Proposal 6



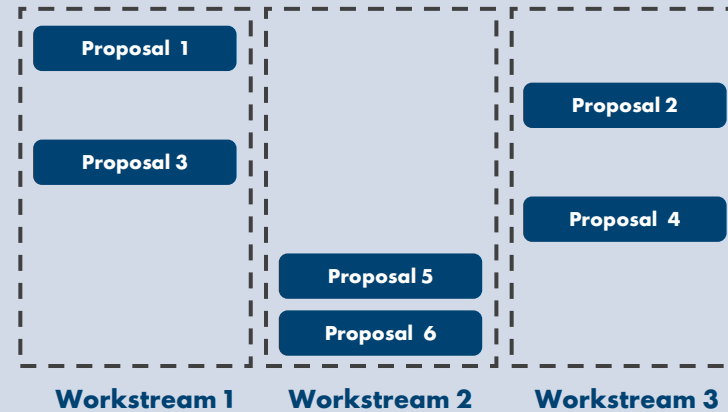


Framing

Brainstorming

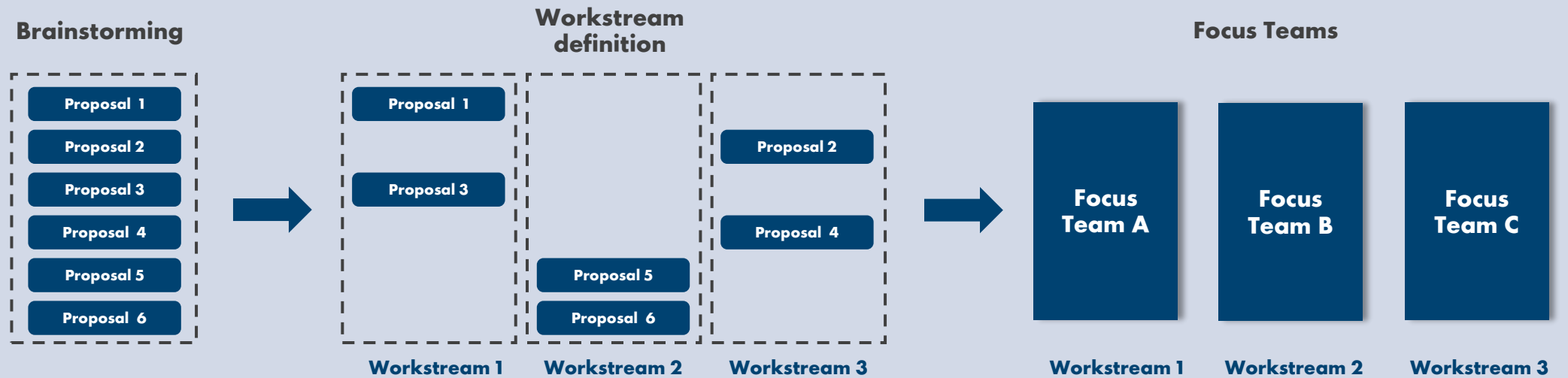


Workstream definition





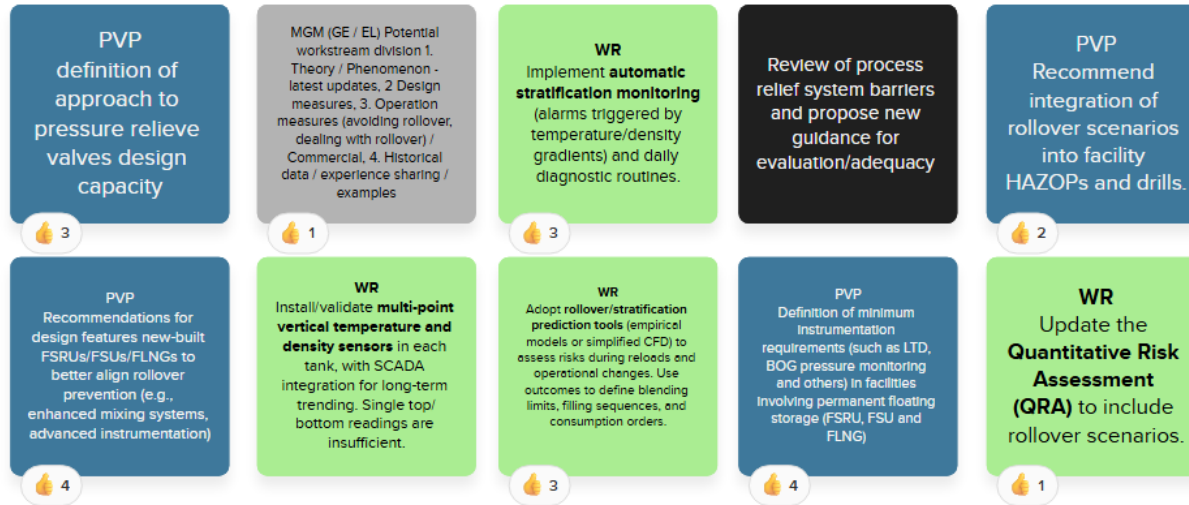
Framing





Framing: Workstreams

Workstream 1 - Hardware Barriers





Framing: Workstreams

Workstream 2 - Containment systems

PVP
Modelling for both Membrane and type B spherical type tanks to provide reader reference examples including time to rollover and rollover evaporation rate



PVP
Cover guidelines on pressurised storage (onshore and IMO type C)

WR
Document any exceptions tied to specific containment systems.

MGM (GE / EL)
include statistical analysis of high heel retention cases which led or did not lead to rollover, including parameters of rollover results



WR
Coordinate with **containment system designers** (GTT, Moss, IHI, etc.) to establish limits and recommendations by tank type (membrane, Moss, full-containment, GST®).



DDP BP is currently conducting scientific research utilising super computers for mathematical modelling combining with operation experience for various simulations



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Framing: Workstreams

Workstream 3 - Operational

<p>FRU Add specific aligned guidance for membrane and type A/type B/type C LNGCs for recommended criteria in terms of density difference and max lighter heel level prior to load heavier parcel, when only bottom filling is available.</p> <p>2</p>	<p>PVP Develop specific operational scenarios for rollover risk (e.g., partial unloading, heel management, boil-off return).</p> <p>5</p>	<p>FRU on LNGC so far rollovers have been lower extend and consequence compared to shore tanks; we need to define if our purpose is to avoid pressure safety valves triggering only, or if we want to avoid any abnormal situation where pressure cannot be controlled properly.</p> <p>2</p>	<p>PVP Recommended practices for rollover prevention during tank loading operations in floating facilities based on the design configuration of the receiving terminal (top/bottom filling available vs only bottom filling).</p> <p>3</p>	<p>WR Document emergency measures for imminent rollover (venting control, authority notification, contingency plans).</p> <p>3</p>	<p>WR Define mitigation routines (recirculation, controlled blending) when stratification is detected.</p> <p>3</p>	<p>WR Define short-term technical responses: increase send-out, recirculate LNG (if possible), controlled blending, or inter-tank transfers to break layers.</p> <p>3</p>	<p>WR Require composition analysis (boil-off curve, C2–C5 fractions, N₂/He traces) before re-loading or major blending operations.</p> <p>1</p>	<p>WR Reflect responsibilities in contracts and nominations: acceptable density/composition ranges, obligations for pre-discharge sampling, and reloading restrictions.</p> <p>1</p>	<p>PVP Add specific guidance figures in terms of max Delta temperature and or density % difference between adjacent measurement points (per cm level difference).</p>
<p>WR Maintain a local incident and near-miss registry and actively share within GIGNL/SIGTTO forums.</p> <p>3</p>	<p>FRU Add more recent examples of rollover occurrence for LNGC</p> <p>3</p>	<p>WR Integrate lessons learned from worldwide FSRU and onshore terminal rollover cases into internal procedures.</p> <p>1</p>	<p>WR Establish clear procedures for bottom vs. top filling, maximum loading rates, and Boil Off management to avoid layering.</p> <p>1</p>	<p>WR Include explicit rules for partial reloads/bottom filling (when permissible, maximum ullage, controlled blending procedures) and pre-loading checklists.</p> <p>1</p>	<p>NA Provide guidance for frequency to run LTD profiles.</p>	<p>NA Provide recommendations for density/temperature deviation alarm settings.</p> <p>1</p>	<p>Abbas AM Add specific guidance for MOSS and GTT type vessels as well with clear guidelines on allowable Max. cargo level/height for loading heavier LNG into lighter grade LNG (Bottom filling).</p> <p>1</p>	<p>AJ Mention the maximum % density difference with respect to heel LNG density for which top/bottom filling will prevent stratification</p>	<p>WR Revise and update density/dp limits and alarm thresholds (not just a fixed 1 kg/m³), incorporating criteria based on tank capacity, containment type, and LNG composition. Evidence from field operations shows fixed limits require technical re-evaluation.</p> <p>1</p>
<p>RE Update the existing content of the paper to reflect current state of the art</p>	<p>NA On introduction section, revise and update LNG demand, Global regasification capacity, LNG liquefaction capacity, (Page 6)</p>	<p>PVP Define recommendations for operators to log stratification data and rollover-related anomalies.</p> <p>5</p>	<p>WR Maintain a database of densities and compositions by origin to evaluate risks when introducing new supply sources.</p> <p>1</p>	<p>WR Define clear communication chains and responsibilities (who halts operations, who authorizes blending), supported by daily logbooks.</p> <p>1</p>	<p>WR Train operators and HSE staff on early stratification detection, trend analysis, and immediate mitigation steps (suspend ops, adjust regasification, escalate to engineering).</p> <p>1</p>	<p>PVP Recommend tailored training modules for FSRU/FSU crews on rollover mechanisms and early warning signs</p> <p>4</p>	<p>LvdWerff (Gasunie) Give guidelines to develop automated Vapour withdrawal rate – temperature increase monitoring based on historical data and operational conditions. Monitoring tool to create alarms in case of too low mass flow rates and LNG temperature rise.</p>		



Framing: Focus Teams

Hardware Barriers

Pablo Vega Perez
Igor Rossi
Paul Decroes
Adrian Ruiz
Richard Ellis
Abbas Mulji
Carlos Guerrero
Jose Navarro
Anne Jose
Lionel Martin
Remi Linotte

Containment Systems

Pablo Vega Perez
Igor Rossi
Dineshsingh Pawar
Remi Linotte
Jose Navarro
Carlos Guerrero
Lionel Martin
Adrian Ruiz
Laurent Spittaël
Francois Ruggieri

Operational

Pablo Vega Perez
Igor Rossi
Lieuwe van der Werff
Anne Jose
Eleni / Georgios
Dineshsingh Pawar
Lionel MARTIN
Abbas Mulji
Nestor Aquino
Francois Ruggieri
Ümit Gürses
William Rincon



Planning

Activity	Start date	End date
TSG working group approval	3 May 2025	5 May 2025
Establish working team and prepare TOR	1 Jun 2025	20 Jun 2025
Kick off meeting	3 Jul 2025	3 Jul 2025
Framing session	1 Sept 2025	25 Sep 2025
Work structure approval by TSG	27 Sep 2025	29 Sep 2025
FT A meeting 1	TBC	TBC
FT B meeting 1	TBC	TBC
FT C meeting 1	TBC	TBC
...	TBC	TBC
FT A meeting 2	TBC	TBC
FT B meeting 2	TBC	TBC
FT C meeting 2	TBC	TBC
...		
Final Draft submission for TSG review	TBC	TBC
Final Draft approval by TSG	TBC	TBC
Quality control	TBC	TBC
Drafting and editing	TBC	TBC
Publishing	TBC	TBC