Working Group #1: Liquefied Natural Gas (LNG) Facility Design & Construction

Summary Report-Out

Roadmapped Research Gaps

Prioritized Gap #1: Develop criteria for cryogenic and fire protection requirements based on hazard modeling study.

The following questions are provided for the roadmapping of each research gap:

1. What is the suggested gap name for this research project?

   - Develop Criteria for Cryogenic and Fireproofing Requirements for LNG Facilities.

2. What is the suggested objective statement for this gap?

   - Provide additional guidance for uniform methodology to evaluate fire-proofing and cryogenic spill protection for LNG facilities.
   - Provide guidance for selecting, applying, and maintaining cryogenic and fireproofing systems designed to limit the extent of cryogenic and fire-related consequences from pool fires and jet fires at LNG facilities.

3. Can any regulatory, congressional, or National Transportation Safety Board (NTSB) drivers (more than one category can be included) be identified as associated with this gap?

   - N/A.

4. What key technical details or scope items are necessary and recommended to be incorporated into the research project?

   - National Fire Protection Association (NFPA) 59A (2001) Section 6.4.1 and 9.1.2.
   - NFPA 59A (2019) Sections 6.7, 12.5, and 12.7.
   - Current PHMSA Research, Vapor Cloud Explosion (VCE) and Cascading Effect on LNG Facility.

- American Petroleum Institute (API) 2218, Fire-Proofing Practices in Petroleum Petrochemical Plants.
- SANDIA National Lab requirements.
- PHMSA LNG FAQs for siting.
- Manufacturing, testing, and guidance documents.
- Underwriters Laboratory (UL) 1709 Testing.
- American Society for Testing and Materials (ASTM).
- NFPA 59A (2019) 16.7.
- Part 193.2511.

5. Which research output is being suggested from the gap (technology development or general knowledge)?

    - General knowledge; industry guidance documents developed as the result of analysis and evaluation of existing research and activities.
    - General knowledge; addition/modification to PHMSA Part 193?

6. [Answer if relevant] What type of data output or tool/model functionality is required to successfully address the gap?

    - N/A.

7. Does the gap address a related consensus standard (i.e., NFPA 59A) or best practice?

    - NFPA 59A.

8. What are anticipated targets or timeframes to complete this research (months)?

    - 12 – 18 Months.

Prioritized Gap #2: Guidance on quantitative and semi-quantitative criteria to perform risk reduction using Hazard and Operability (HAZOP) and Layers of Protection Analysis (LOPA). Guidance could be in form of FAQ or other means.

The following questions are provided for the roadmapping of each research gap:

1. What is the suggested gap name for this research project?

- Development of Guidance for Managing Process Safety Risk Using HAZOP and LOPA Techniques for LNG facilities.

2. What is the suggested objective statement for this gap?

   - Use of HAZOP and LOPA techniques to identify and achieve LNG process safety risk reduction.

3. Can any regulatory, congressional, or NTSB drivers (more than one category can be included) be identified as associated with this gap?

   - N/A.

4. What key technical details or scope items are necessary and recommended to be incorporated into the research project?

   - Incorporate relevant guidance from the documents listed below to develop best practices and guidelines:

     - Guidance from Center for Chemical Process Safety (CCPS).
     - Guidelines for Hazard Evaluation Procedures (CCPS).
     - LOPA Book, Simplified Process Risk Assessment (CCPS).
     - Occupational Safety and Health Administration (OSHA) 29 CFR 1910.119.

5. Which research output is being suggested from the gap (technology development or general knowledge)?

   - General knowledge; industry guidance documents developed as the result of analysis and evaluation of existing research and activities.
   - General knowledge; addition/modification to PHMSA Part 193?

6. [Answer if relevant] What type of data output or tool/model functionality is required to successfully address the gap?

   - N/A.

7. Does the gap address a related consensus standard (i.e., NFPA 59A) or best practice?

   - Guidance from CCPS.
   - Guidelines for Hazard Evaluation Procedures (CCPS).
   - LOPA Book, Simplified Process Risk Assessment (CCPS).

- OSHA 29 CFR 1910.119.

8. What are anticipated targets or timeframes to complete this research (months)?

   - 12 Months.

Prioritized Gap #3: Effective use of remote impoundment methods, pipe in pipe, spacing/storage to mitigate risks of chain failure events and fire.

The following questions are provided for the roadmapping of each research gap:

1. What is the suggested gap name for this research project?

   - Use of Secondary Containment Methods to Reduce the Effect of Spills and Pool Fires.

2. What is the suggested objective statement for this gap?

   - Provide guidance on use of secondary containment methods to reduce the effect of spills and pool fires.

3. Can any regulatory, congressional, or NTSB drivers (more than one category can be included) be identified as associated with this gap?

   - N/A.

4. What key technical details or scope items are necessary and recommended to be incorporated into the research project?

   - Conveyance of spills to impoundment.
   - Escalation of fire incidents.
   - Effect of pool fire on pressurized vessels and structure systems and components.
   - Local impoundment vs. remote impoundment.
   - Equipment spacing to prevent escalation due to fires.
   - Effectiveness of different collection systems prevention LNG from entering the waterway for different hole size and operation pressures.

5. Which research output is being suggested from the gap (technology development or general knowledge)?

- General knowledge; guidance documents.

6. [Answer if relevant] What type of data output or tool/model functionality is required to successfully address the gap?

   - N/A.

7. Does the gap address a related consensus standard (i.e., NFPA 59A) or best practice?

   - 49 CFR 193.
   - NFPA 59A.
   - API 2218, Fire-Proofing Practices in Petroleum Petrochemical Plants.

8. What are anticipated targets or timeframes to complete this research (months)?

   - 12 – 18 Months (MIN).

Prioritized Gap #4: Modern plant designs usually include a mix of manual, remote, and automatic valving, but each design is different. Research to determine the appropriate locations for remote control valves vs manual valves in designing a plant, to better protect personnel safety and minimize volumes of a release.

The following questions are provided for the roadmapping of each research gap:

1. What is the suggested gap name for this research project?

   - Selection and Placement of Remote, Automatic, and Manual Isolation Valves for Personnel Safety and to Minimize Release Volumes.

2. What is the suggested objective statement for this gap?

   - Provide guidance as to where remote-control valves could be placed for personnel safety and reliability.

3. Can any regulatory, congressional, or NTSB drivers (more than one category can be included) be identified as associated with this gap?

   - N/A.

4. What key technical details or scope items are necessary and recommended to be incorporated into the research project?

    - NFPA 59A (2001) 6.3.3.4.
    - NFPA 59A (2019) 15.6.8 and 17.3.2.2.
    - International Electrotechnical Commission (IEC) Standards 61511 and 61508 for reliability.
    - International Society of Automation (ISA) Guidance TR84.
    - API 2218, Fireproofing Practices in Petroleum Petrochemical Plants.
    - Guidance on use of remote and automatic isolation vs. manual isolation for safe access.
    - Reliability of automatic shutdown during an event (impact of heat/fire exposure on valve components, control cables & required protections to prevent damage).
    - Nuclear Regulatory Commission Regulation (NUREG)/CR-6931, Volume 1: https://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6931/v1/index.html.
    - NUREG/CR-7100: https://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr7100/final/index.html.

5. Which research output is being suggested from the gap (technology development or general knowledge)?

    - General knowledge; guidance documents as the result of analysis and evaluation of existing research and activities.

6. [Answer if relevant] What type of data output or tool/model functionality is required to successfully address the gap?

    - N/A.

7. Does the gap address a related consensus standard (i.e., NFPA 59A) or best practice?

    - NFPA 59A.

8. What are anticipated targets or timeframes to complete this research (months)?

    - 12 – 18 Months.

Prioritized Gap #5: Study spills of LNG near waterways; the overpressure cause by rapid phase transition of LNG which has entered the waterway.

The following questions are provided for the roadmapping of each research gap:

1. What is the suggested gap name for this research project?

   - Effect of LNG Spill on Water Resulting in Rapid Phase Transition (RPT).

2. What is the suggested objective statement for this gap?

   - Conduct research to gather data for future modeling for LNG spill on water and its effect.

3. Can any regulatory, congressional, or NTSB drivers (more than one category can be included) be identified as associated with this gap?

   - Federal Energy Regulatory Commission (FERC) Condition.

4. What key technical details or scope items are necessary and recommended to be incorporated into the research project?

   - Perform lab research to enable future modeling.
   - Understand probability of RPT occurrences.
   - Understand hazard distances for dispersion and pool fire.

5. Which research output is being suggested from the gap (technology development or general knowledge)?

   - General knowledge; lab data.

6. [Answer if relevant] What type of data output or tool/model functionality is required to successfully address the gap?

   - N/A.

7. Does the gap address a related consensus standard (i.e., NFPA 59A) or best practice?

   - NFPA 59A.
   - 33 CFR Part 127.

8. What are anticipated targets or timeframes to complete this research (months)?

    - 12 – 18 Months.

Prioritized Gap #6: Technologies for reducing the hydrogen concentrations (to an acceptable level) in the feed gas to existing LNG facilities; maximum hydrogen concentrations and technologies to reduce hydrogen concentrations.

The following questions are provided for the roadmapping of each research gap:

1. What is the suggested gap name for this research project?

    - Impacts of Hydrogen in Feed Gas on LNG Facilities and Evaluation of Hydrogen Reduction Technologies.

2. What is the suggested objective statement for this gap?

    - Evaluate technologies to detect hydrogen in feed gas, acceptable levels of hydrogen, technologies to reduce this to acceptable levels, impacts to piping and equipment, and impacts to operations.

3. Can any regulatory, congressional, or NTSB drivers (more than one category can be included) be identified as associated with this gap?

    - Note: Political push to inject hydrogen in NG system; this will impact LNG facilities.

4. What key technical details or scope items are necessary and recommended to be incorporated into the research project?

    - Data pertaining to the amount of hydrogen in natural gas pipelines.
    - Technologies to detect hydrogen in feed gas.
    - Acceptable levels of hydrogen.
    - Technologies to reduce this to acceptable levels.
    - Impacts to piping and equipment (materials of construction, etc.).
    - Impacts to operations (liquefaction, trucking import of methane refrigerant, leak detection systems, fire detection systems, seal designs, relief systems, storage tank monitoring, etc.).

5. Which research output is being suggested from the gap (technology development or general knowledge)?

    - General knowledge; guidance documents.

6. [Answer if relevant] What type of data output or tool/model functionality is required to successfully address the gap?

    - N/A.

7. Does the gap address a related consensus standard (i.e., NFPA 59A) or best practice?

    - May ID gaps in NFPA 59A and 49 CFR 193.

8. What are anticipated targets or timeframes to complete this research (months)?

    - 12 – 18 Months.

Prioritized Gap #7: how would PHMSA adapt new innovative technologies for geotechnical investigation for the LNG facility site?

The following questions are provided for the roadmapping of each research gap:

1. What is the suggested gap name for this research project?

    - Technology Advancements in Geotechnical Investigation Methodology and Ground Improvement for New and Existing LNG Facilities.

2. What is the suggested objective statement for this gap?

    - Develop guidance pertaining to technological advancements in geotechnical investigation methodologies and ground improvements for LNG facilities.

3. Can any regulatory, congressional, or NTSB drivers (more than one category can be included) be identified as associated with this gap?

    - N/A.

4. What key technical details or scope items are necessary and recommended to be incorporated into the research project?

   - Use in-situ investigation and modeling to determine underground hazards.
   - FERC 2017 Design Guidance Manual Appendix 13J.
   - NFPA 59A (2001) Section 2.1.4 states: Soil and general investigations of the site shall be made to determine the design basis for the facility.
   - 18 CFR 153 and 380.
   - American Concrete Institute (ACI) 376.

5. Which research output is being suggested from the gap (technology development or general knowledge)?

   - General knowledge; guidance documents.

6. [Answer if relevant] What type of data output or tool/model functionality is required to successfully address the gap?

   - N/A.

7. Does the gap address a related consensus standard (i.e., NFPA 59A) or best practice?

   - NFPA 59A.
   - 49 CFR 193, Subpart C incorporates 59A 2001, section 2.1.4 requires soil and general investigation.

8. What are anticipated targets or timeframes to complete this research (months)?

   - 12 Months.

Prioritized Gap #8: PHMSA development and research on Piping stress analysis regarding vibration impacts on small piping system under 2 inches.

The following questions are provided for the roadmapping of each research gap:

1. What is the suggested gap name for this research project?

   - Pipe Stress Analysis on Small Piping Systems (under 2 inches) Due to Vibration Impacts from Nearby Rotating Equipment.

2. What is the suggested objective statement for this gap?

    - Evaluate the impacts of vibrations from nearby rotating equipment on all small piping systems (under 2 inches).

3. Can any regulatory, congressional, or NTSB drivers (more than one category can be included) be identified as associated with this gap?

    - N/A.

4. What key technical details or scope items are necessary and recommended to be incorporated into the research project?

    - American Society of Mechanical Engineers (ASME) B 31.3.
    - NFPA 59A.
    - Schedule 40, 80 (pipe thicknesses).
    - Cross-connections.
    - Include tubing as an element of the entire piping system.

5. Which research output is being suggested from the gap (technology development or general knowledge)?

    - General knowledge; guidance documents and criteria.

6. [Answer if relevant] What type of data output or tool/model functionality is required to successfully address the gap?

    - Caesar.
    - AutoPIPE.

7. Does the gap address a related consensus standard (i.e., NFPA 59A) or best practice?

    - ASME B31.3.
    - NFPA 59A.

8. What are anticipated targets or timeframes to complete this research (months)?

    - 12 – 18 Months.

List of Prioritized Consolidated Gaps

#	**Consolidated Gap**
1.	Develop criteria for cryogenic and fire protection requirements based on hazard modeling study.
2.	Modern plant designs usually include a mix of manual, remote, and automatic valving, but each design is different. Research to determine the appropriate locations for remote control valves vs manual valves in designing a plant, to better protect personnel safety and minimize volumes of a release.
3.	Effective use of remote impoundment of methods, pipe in pipe, spacing/storage to mitigate risks of chain failure events and fire.
4.	Technologies for reducing the hydrogen concentrations (to an acceptable level) in the feed gas to existing LNG facilities.
5.	Study spill collection of LNG piping near waterways. 1.) The effectiveness of different collection systems prevention LNG from entering the waterway for different hole size and operation pressures and 2.) the overpressure cause by rapid phase transition of LNG which has entered the waterway.
6.	Effectiveness of different isolation philosophies, and when to use them (i.e., double block and bleed, what piping pressure class to use DBB? When is removable spool preferred vs a blind?).
7.	how would PHMSA adapt new innovative technologies for geotechnical investigation for the LNG facility site?
8.	Guidance on quantitative and semi-quantitative criteria to perform risk reduction using HAZOP and LOPA. Guidance could be in form of FAQ or other means.
9.	PHMSA development and research on Piping stress analysis regarding vibration impacts on small piping system under 2 inches.
10.	Minimum amount of Hydrogen (H_2) that can be exposed to plant materials that would be small enough too not affect materials by HSCC. Of particular concern is 9% Ni Steel.
11.	Overall impacts of hydrogen in pipelines to the entire LNG facility. Do codes and standards used for LNG facilities need to be updated for hydrogen?
12.	Research and development regarding the design of Seismic Isolator for the LNG storage tank in the high seismic region.
13.	Impact of hydrogen concentration, pressure and temperature on pipeline integrity.
14.	Lab or in-field experiment to validate the thermodynamic methods, commercially available software (process and computational fluid dynamics (CFD)) outputs H_2 has on the liquefaction process, LNG storage tank, vapor space, liquid space, and top/bottom fill.
15.	Develop guidance for conducting Preliminary Hazard Analysis (PHA) of LNG facilities (small scale and large scale) and require LNG facilities to conduct PHA prior to construction and PHA revalidations at least every 5 years.
16.	Pipeline structure safety design and flaw detection under extreme loading conditions, which considers multiaxial and complex stress loadings, hydrogen embrittlement, and material aging.
17.	Qualify and quantify environmental injustice in siting and design choices and what should be done to enact justice.

18.	Review relief system design basis and calculations and determine how hydrogen enriched LNG will affect relief valve overpressure scenarios, sizing calculations, etc.
19.	Review incident history of hydrogen induced embrittlement at refineries and develop best practices that should be applied in the design and construction of LNG facilities (i.e., materials of construction) and ways to detect/monitor for hydrogen embrittlement scenarios.
20.	Liquefaction – Evaluation of applicable refrigerants and changes in the environmental impact as available blends change.
21.	Hurricane/severe weather design research question focusing on whether environmental parameter thresholds underlying existing standards will remain valid for decades in light of climate change and more severe extreme storms.
22.	Design considerations for safety to include: explosion risks of LNG tanks and refrigerant tanks and then what happens when there is an explosion (Emergency Response Plan).
23.	Design considerations for shutdown and malfunction events: how can there be zero air emissions after a storm for example.
24.	Cumulative effects: pollution (air, water, noise) including fugitive emissions of operation, construction, and malfunction of facilities; effects on workers, surrounding communities and public health.
25.	Pipeline monitoring for hydrogen carrier pipelines – leak detection including odorization.
26.	If H_2 is removed from LNG feedstock, how low can the levels be brought down to "economically?
27.	Evaluating the minimum number of fixed points spaced around the circumference and within interior a tank needs such that it does not overstress, cause buckling, or exceed other API limits.
28.	Specific siting guidelines for Gravity Based Structures (GBS) for LNG storage, including storage tanks mounted on top of GBS and GBS where the LNG is stored inside the concrete caisson. Facility Siting should consider the potential role of GBS in enhancing a creatinine retaining walls.
29.	Development of computational tools or models based on fracture mechanics or material corrosion will help to evaluate and monitor the vessel safety.
30.	It is likely that open expansion LNG facilities would be most affected. These facilities would need to be redesigned for each HENG H2 concentration – is there any recourse for such facilities other than to switch to a non-open expansion system?
31.	Design considerations for decommissioning all facilities (including a cost-benefit analysis to include the lifespan of the terminal and pipelines); LCA of Pipeline Replacement.