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Not your father's 59A: how the LNG safety standard has evolved to adapt to the industry changes over the last 20 years

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Abstract

After over 20 years, the Department of Transportation's Pipeline and Hazardous Materials Safety Administration (DOT-PHMSA) appears to be making progress to revise 49 CFR 193, the section of Code of Federal Regulations that applies to liquefied natural gas (LNG) facilities. While the actual promulgation of the revised regulations is likely another year or so away, it is widely expected that the revised rules will rely heavily upon the 2023 (or perhaps 2026) edition of NFPA 59A, the *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*. NFPA 59A is a consensus standard, developed and maintained by the National Fire Protection Association through the volunteer efforts of LNG stakeholders across a broad spectrum of interests, such as: owners and operators; federal and State regulators; manufacturers; insurance representatives; special experts; and others.

This paper will review the evolution of the LNG industry in the United States, particularly focusing on the last 20+ years, and describe how NFPA 59A evolved over time to keep abreast of changes in the LNG industry, such as the drastic switch from LNG import to liquefaction and export, the evolution of hazard modeling tools, and the more recent burst of small scale facilities aimed at ship bunkering.

1 Background

On May 5, 2025, DOT-PHMSA published an Advanced Notice of Public Rulemaking (ANPRM), the first official step towards updating federal regulations for Liquefied Natural Gas (LNG) facilities under their jurisdiction, which are codified in Title 49 of the Code of Federal regulations, Part 193 (49 CFR 193) [1]. These regulations have not been updated in over 20 years, with the last major update being in 2004. DOT-PHMSA LNG regulations incorporate by reference the 2001 edition of NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)* [2], and broadly draw from or defer to this standard on numerous requirements.

The upcoming regulatory update presents an opportunity to reflect over the evolution of the LNG industry in the United States over the past two decades, and to discuss how the LNG community has been advancing safety standards to keep pace with technology and market evolution. Thus, the focus of this paper is not on describing changes to safety standards (particularly NFPA 59A) line-by-line and edition-by-edition, but on drawing causal connections between changes in the U.S. LNG industry and changes in safety requirements. The goal of this approach is to provide the context that drove the most significant changes to NFPA 59A since the 2001 edition (i.e., facility siting, small scale LNG, and others), in order to better prepare interested parties to understand the rationale behind what are expected to be significant regulatory requirements.

2 The LNG Regulatory Landscape

LNG is the only flammable or hazardous material for which specific and detailed requirements exist in U.S. federal regulations for the siting and construction of storage, handling, and transfer facilities [3]. Furthermore, LNG facilities in the United States are subject to different sets of regulations depending on the authority having jurisdiction (AHJ) over the facility, which varies depending on where the facility is located (i.e., on land or over water) and what type of commerce it is involved in (e.g., international, interstate, or intrastate). The following gives a brief overview of the different regulatory agencies for LNG facilities in the United States.

2.1 Department of Transportation's Pipeline and Hazardous Materials Safety Administration

The Natural Gas Pipeline Safety Act of 1968 (NGPSA) authorizes DOT to regulate pipeline transportation of natural gas and other gases, as well as the transportation and storage of LNG. DOT-PHMSA therefore has jurisdiction over LNG facilities which receive or deliver natural gas through a pipeline regulated by DOT under 49 CFR Part 192. As a result, DOT-PHMSA can have jurisdiction over LNG import terminals, export terminals, both interstate and intrastate LNG peakshaving facilities, as well as other types of LNG facilities. DOT-PHMSA, however, does not have jurisdiction over:

a) facilities which are the ultimate consumer of LNG or natural gas – for example, an LNG facility whose sole purpose is to provide LNG for fuel in on-site power generation;
b) facilities used in the course of natural gas treatment or hydrocarbon extraction which do not store LNG – for example, a natural gas pretreatment facility separate from an LNG facility;
c) any LNG facility located in navigable water, such as an floating storage and regasification unit (FSRU) of floating LNG liquefaction (FLNG) vessel located in either state or federal waters.

2.2 Federal Energy Regulatory Commission

The Federal Energy Regulatory Commission (FERC) is responsible for authorizing the siting and construction of onshore and near-shore LNG import or export facilities under Section 3 of the Natural Gas Act. Therefore, FERC has jurisdiction over the import and export of natural gas to foreign countries. As such, any LNG facility (either import or export terminal) located on land (on shore) or in state waters (near shore) is very likely to be under FERC jurisdiction. FERC does not have jurisdiction over LNG facilities located outside of State waters (offshore), as those are under the jurisdiction of the Maritime Administration (see below).

FERC also has jurisdiction over LNG peakshavers involved in the transportation of natural gas across State lines (interstate); however, FERC does not have jurisdiction over LNG peakshavers that only participate in intrastate commerce, as those are regulated at the State level.

2.3 Maritime Administration

The Deepwater Port Act (DWPA), as amended, establishes a licensing system for deepwater ports for the import and export of oil and natural gas that are located offshore (i.e., beyond State waters). The DWPA assigned the authority to issue or deny deepwater port licenses to the Secretary of Transportation, who has in turn delegated such authority to the Maritime Administrator. Therefore, any LNG facility located offshore (beyond State waters) is subject to the Maritime Administration (MARAD), which shares its responsibility for the safety, security, and environmental review of deepwater port terminals with the U.S. Coast Guard (USCG).

2.4 U.S. Coast Guard

In addition to collaborating with MARAD on deepwater port applications, USCG regulates the marine transfer areas for each waterfront land-based facility handling LNG, according to the requirements in 33 CFR Part 127. Additionally, the USCG conducts waterway suitability assessments to address navigation safety and port security issues associated with LNG ship traffic.

2.5 State or Local

LNG facilities that are not under the jurisdiction of one or more of the federal agencies listed above, may fall under the jurisdiction of the State, County, or City in which they are located. The agency or commission responsible for regulating LNG facilities varies State by State, and so do the applicable regulations and, as a result, the applicable edition of NFPA 59A. For example, in Massachusetts, the Energy Facility Siting Board regulates the siting and construction of major energy infrastructure, including natural gas storage facilities; 980 CMR 10.00 sets the regulatory standards for siting intrastate LNG storage facilities, and explicitly notes the concurrent authority of the Department of Public Utilities over their safe design and operation. In Washington, instead, the Utilities and Transport Commission is the state regulator for intrastate LNG facilities, enforces safety standards and acts as the lead inspector; however, different agencies (e.g., local governments, the Washington State Dept. of Ecology, etc.) may lead the environmental review under the State Environmental Policy Act, which has been used in legal challenges to LNG facilities.

3 The LNG Standard: NFPA 59A

LNG industry stakeholders have been collaborating for decades to develop safety standards aimed at preventing accidents, minimizing their consequences, and overall protecting both LNG facility personnel and the public. The product of this collaboration is a comprehensive safety standard governing the siting, design, construction, operation, and maintenance of LNG plants, published by the National Fire Protection Association (NFPA) as "*NFPA 59A, Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*". The standard contains the minimum criteria to be complied with for plant siting and layout, locations of process equipment, storage container design, safety assessment and calculation of the extent of exclusion zones, fire protection, safety and security, maintenance, personnel training, etc.

By virtue of being created by a recognized standards-producing organization such as NFPA, and of reflecting substantial agreement among a broad and balanced group of stakeholders, NFPA 59A is a “consensus standard”. Thus, even though it is written in regulatory (i.e., enforceable) language, it is not a regulation in and of itself; however, it becomes enforceable when it is incorporated into a set of regulations – for example, the current edition of 49 CFR 193 (DOT-PHMSA’s LNG regulations) incorporates by reference the 2001 edition of NFPA 59A.

NFPA 59A, as most NFPA standards, is revised on a recurring three-year cycle, which allows it to keep pace with changes in LNG technologies and markets to reflect current best practices, as will be discussed in the remainder of this paper.

4 U.S. LNG in the 20th Century

The U.S. LNG industry began taking shape in the late 1960s/early 1970s as a response to growing natural gas demand and concerns about domestic shortages; this is when the first LNG import terminals were built (first Everett, Massachusetts and Elba Island, Georgia; later, Cove Point, Maryland and Lake Charles, Louisiana). However, US LNG imports stagnated in the 1980s and early 1990s due to gas market deregulation and domestic oversupply; the Everett terminal was the only one that remained in operation due to the local demand for natural gas in the Northeast. During the same time period, however, the use of LNG for peakshaving purposes kept growing, due to the need for reliable gas supply in the winter. As a result, the US LNG industry in the 1990s consisted of numerous small peakshavers and a few, largely unutilized, import terminals.

The late 1990s saw a rapid increase in natural gas demand in the United States, which led to concerns of a supply shortfall; coupled with a growing LNG production in other countries (e.g., Qatar, Australia) this led to a rush to developing LNG import terminals. As shown in Figure 1, in 2006 there were over 40 LNG import terminals in North America (nearly 90% of them in the United States), at various stages of development.

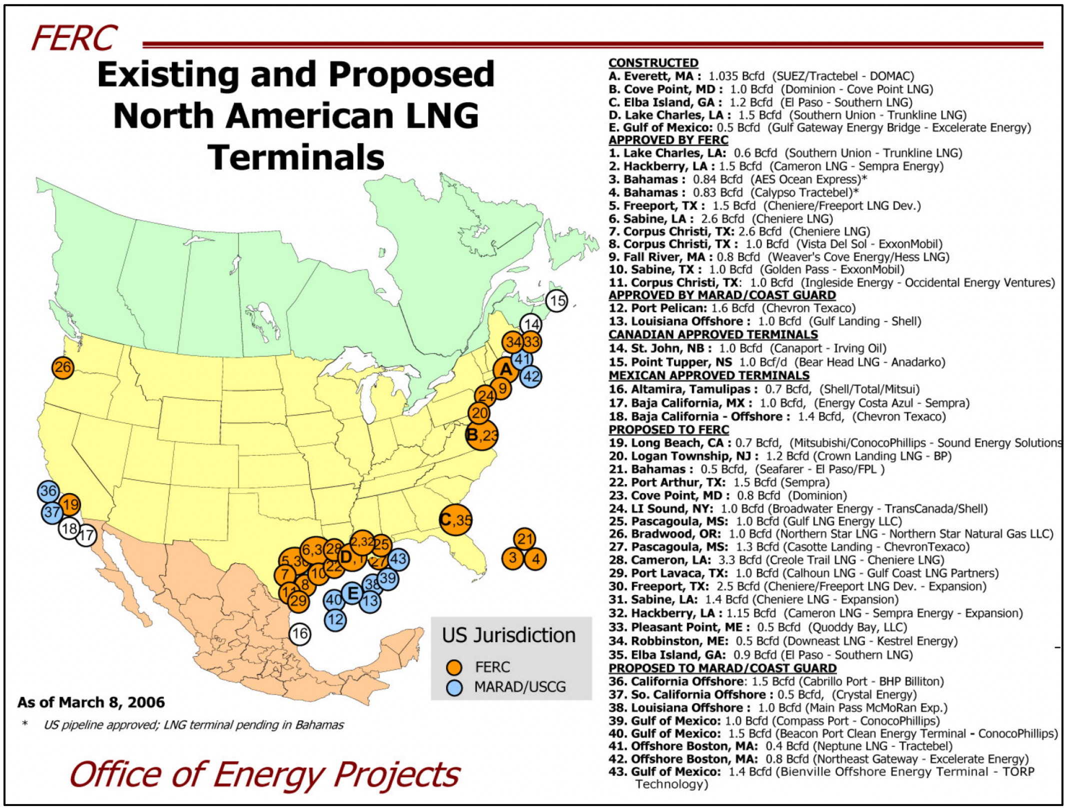

Figure 1: LNG import terminals in the Federal permitting process in 2006

4.1 NFPA 59A: the Origins

The first version of the NFPA 59A Standard was officially adopted in 1967, under the purview of the Committee on Fuel Gases. Two years later, the Committee on Liquefied Natural Gas was established for the purpose of expanding the scope of 59A by leveraging the American Petroleum Institute's standard PUBL 25 IOA, "*Design and construction of Liquefied Petroleum Gas (LPG) Installations*" [3]; the expanded scope edition was adopted in 1971.

From a public safety standpoint, the "early" LNG facilities in the United States consisted of one or more large storage tanks (most being of the single containment type) with large capacity basins to collect potential spills of LNG due to a failure of the LNG transfer lines (i.e., the largest flow lines within the plant). Therefore, NFPA 59A, 1971 edition focused the public safety requirements on ensuring that the potential consequences of large LNG sendout releases, both ignited and unignited, would not extend to publicly accessible areas. The potential hazards from LNG releases in other areas of the plant were considered minor and bounded by the LNG tank sendout case. Subsequent editions of NFPA 59A, released periodically through 2001, included incremental updates but retained the original focus on the LNG storage tanks being the main public safety hazard.

As discussed in detail by Raj and Lemoff [4], NFPA 59A, as currently incorporated in DOT-PHMSA regulations, is prescriptive - that is, it defines the characteristics of accidents to be considered including location, rate, and duration, as well as the types of hazards to be evaluated and the threshold values to be considered. This appears anachronistic in today's world, where risk-based safety studies are the norm for most industries, as well as for the LNG industry in several countries. However, it is important to note that, in the early 1970s (when the "expanded scope" NFPA 59A was first released), the concept of quantitative risk assessment (QRA) was in its infancy: the WASH-1400 report, released in 1974 by the Atomic Energy Commission [5], is generally considered to have introduced the concept of risk assessment into safety regulations, and the first QRA in the oil and gas industry did not get published until 1978 [6]. This historical context, coupled with the lack of evolution in the US LNG industry between approximately 1970 and 2007, explains why the public safety (i.e., siting) requirements in NFPA 59A remained prescriptive for so many years, even though other industries eventually adopted a risk-based approach. In 2004, DOT-PHMSA regulations for LNG facilities were updated and incorporated by reference the 2001 edition of NFPA 59A; while that edition represented the best safety practices for LNG facilities at the time, the LNG industry evolved significantly over the 20 years. As the rest of this paper will discuss, NFPA 59A underwent significant revisions to keep pace with the industry changes; however, DOT-PHMSA regulations have yet to be revised since then, making them largely anachronistic and difficult to comply with.

During the LNG import phase, some notable changes began to occur in the LNG industry – specifically, more and more new projects opted to install double or full containment tanks instead of the single containment tanks that were the common choice until then. The main advantage of these tanks is that the outer tank provides secondary containment, thus eliminating the need for a large impoundment area and the even larger thermal radiation exclusion zones associated with it. The growing use of full containment tanks led to changes in NFPA 59A: starting with the 2006 edition, siting requirements were updated to address the new tanks; additionally, seismic design criteria for LNG containers were revised to correlate with the requirements of ASCE 7, "*Minimum Design Loads for Buildings and Other Structures*" [7].

5 U.S. LNG Post Shale-Gas Revolution

The "shale gas revolution" refers to the combination of technology advancements including hydraulic fracturing (fracking) and horizontal drilling, that enabled the United States to significantly increase its production of oil and natural gas, particularly from tight oil formations. The dramatic growth in domestic natural gas production flipped the US LNG industry on its head: companies that had built marine terminals for the import of LNG began converting those facilities for liquefaction of pipeline gas in order to export LNG. In fact, the United States became a net exporter of LNG by 2016 and, by 2023, it was the largest exporter of LNG in the world according to the National Center for Energy Analytics [8]. Figure 2 shows three maps that, together, identify all FERC-jurisdictional LNG export terminals (including expansion projects for operating terminals) that are existing, approved but not yet built, or proposed in the United States as of March 3rd, 2026.

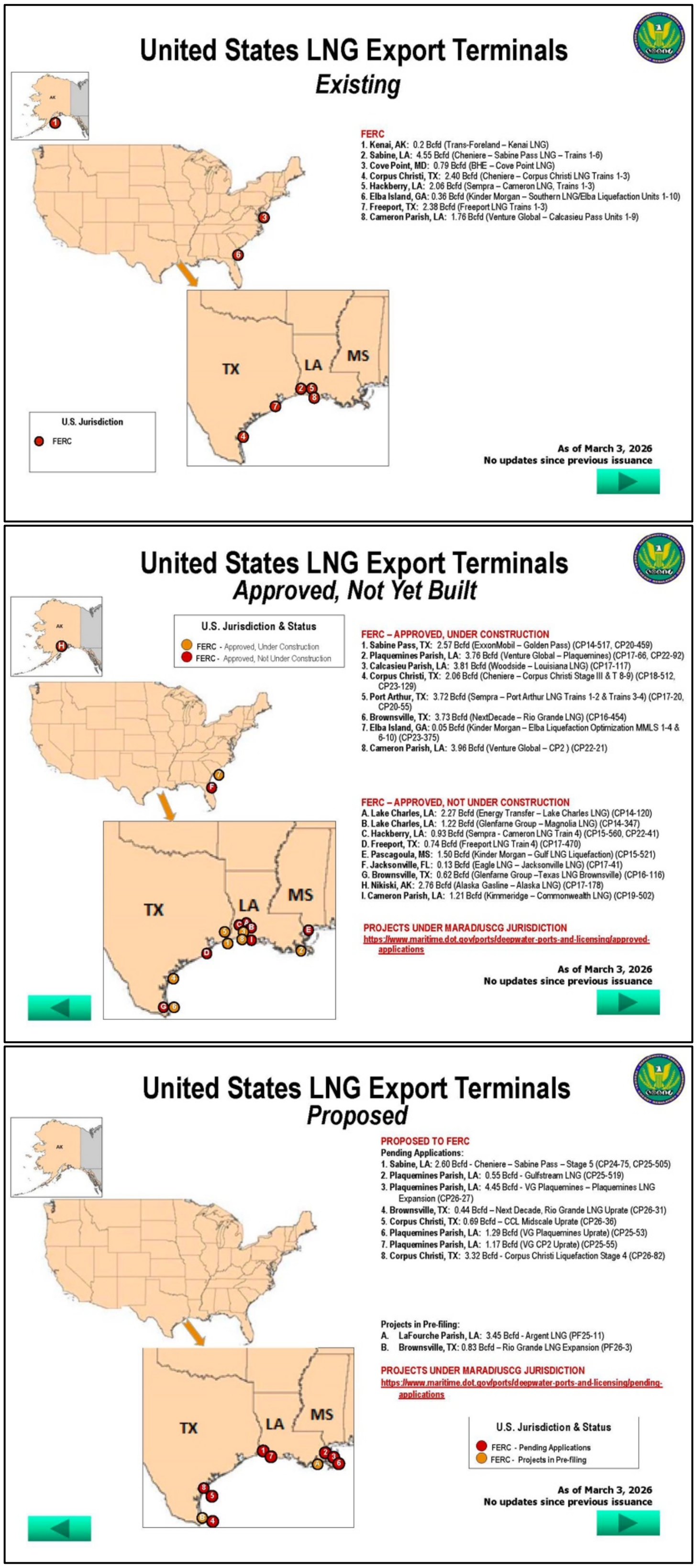

Figure 2: FERC-jurisdictional LNG export terminals in 2026

The drastic change from LNG import to export brought significant challenges in the safety and regulatory arenas, as LNG liquefaction plants – especially at the "world scale" of export facilities – are much more complex than LNG import and regasification plants; liquefaction also introduces "new" hydrocarbons (e.g., propane, pentane, ethylene) into LNG facilities, and with them "new" hazards such as vapor cloud explosions. As discussed by Edwards et al. [9], with the shift to liquefaction and LNG exports, standards and regulations became suddenly inadequate to address the new technology and its safety requirements: the simple application of existing regasification-based requirements to large liquefaction plants, in fact, would neglect some of the most critical hazard scenarios that can actually drive the plant layout as well as the necessary separation from adjacent plants or public areas.

Before discussing the evolution of NFPA 59A in response to the changing US LNG industry, the following subsections describe in more detail the different types of LNG facilities currently dotting the LNG landscape.

5.1 Export

The rapid growth of LNG liquefaction capacity in the US has been already discussed and demonstrated in Figure 2. World-class export facilities can liquefy 5 to more than 70 million tonnes per annum (MTPA) and have storage capacities on the order of 160,000 to 270,000 m^3 per tank, with most facilities having multiple storage tanks. Figure 3, which shows a recent aerial view of Sabine Pass LNG, in Cameron Parish, Louisiana, provides an example of the footprint of these facilities as well as their technical complexity.

Figure 3: Aerial view (dated 4/7/2025) of the Sabine Pass LNG export facility

5.2 Small Scale Liquefaction/Peakshaving

At the opposite end of the spectrum in terms of facility size are over 100 small scale facilities whose main purpose is peakshaving; many of these facilities include a small on-site liquefaction capacity in order to store LNG when there is excess natural gas capacity in the pipeline (typically during non-winter months), while other peakshavers receive LNG for their storage tanks via truck. During the winter months, when natural gas capacity in the pipelines is stressed, the peakshavers vaporize the LNG to re-supply the pipelines.

While LNG peakshaving has been performed for decades, more and more facilities are now adding truck loading capabilities to support a growing market for LNG as bunker and transportation fuel. Small and mid-scale baseload facilities for supply of transportation fuels should continue to expand in numbers as vehicle fueling, and bunkering is utilized in greater volumes.

5.3 Transportation

The U.S. Energy Information Administration notes that ships, trucks, and buses with specially designed LNG tanks already used LNG as fuel in the U.S. before 2007 [10]. However, transportation did not become a mainstream application of LNG until low gas prices increased interest in this opportunity. Today, LNG is primarily used for road transportation in heavy-duty, long-haul trucking, where it provides cleaner emissions than diesel and superior range compared to Compressed Natural Gas because of its density.

5.4 Bunkering

LNG is becoming increasingly popular as bunkering fuel for barges, offshore supply vehicles or ships for similar reasons as LNG trucking. In addition, environmental regulations have imposed more stringent limits for ships in emission control areas surrounding the continental United States and Hawaii [11]. Therefore, bunkering of sea-going vessels with LNG is an activity in rapid growth.

5.5 Rocket Fuel

In addition to road and marine transportation, LNG has seen a rapid growth as rocket fuel over the last few years. Numerous companies developing rockets to launch satellites into orbit have been developing methane-fueled rockets. There are several reasons for this trend towards LNG-fueled rockets, including: methane performs better than kerosene and poses fewer operational challenges than hydrogen; the clean burning characteristics of methane reduce engine fouling (again, compared with kerosene), reducing the time and cost to turn around a rocket for re-use; finally, the broad availability and low cost of LNG make it an economically advantageous choice.

6 Regulatory Changes since 2006

As described in the previous section, the US transition from LNG imports to LNG exports in the 2010-2020 range led to a fundamental change in the complexity of LNG facilities and the regulations and standards around them. While the portion of plant between the marine transfer area and the LNG storage tanks remains similar between LNG export and import terminals (neglecting the opposite LNG flow direction and the frequency of LNG carrier loading vs. unloading), the infrastructure necessary to liquefy natural gas is significantly more complex than that required to regasify LNG. The process areas for liquefaction are generally larger and more congested, and they utilize heavier hydrocarbons than methane, which results in new and/or more severe hazards than are typically considered for LNG import and regasification.

None of these changes are accounted for in LNG regulations, which were written before the shale gas revolution and remain unchanged. Regulators did acknowledge the changes occurring in the industry and their implications in terms of public safety; without an opportunity to update the actual regulations, regulators pursued a much less formal and rigorous approach to inform the LNG industry of their revised expectations for LNG facility siting: in 2014, DOT-PHMSA established a Frequently Asked Questions (the "FAQ page") website which laid out the expectations for how facility siting studies had to be performed in order to obtain regulatory approval [12]. The FAQ page introduced requirements to evaluate releases from piping, not just carrying LNG but any flammable and/or toxic stream (i.e., refrigerants, condensates, acid gas, etc.); it also introduced the need to evaluate additional hazards such as jet fires, vapor cloud explosions, and cascading events, none of which are explicitly identified in 49 CFR 193. The FAQ page was updated several times over the years to address new concerns as well as the evolution of regulatory expectations; the page remains active to date and is routinely followed and referenced in DOT-PHMSA-jurisdictional LNG facility siting studies.

Not surprisingly, since the FAQs were released and updated without the public input required for the release or update of regulations, the adoption of the FAQs as pseudo-regulations caused several unintended consequences. The most egregious consequence was the adverse impact on the ability of small-scale LNG facilities to be permitted: while large export facilities tend to occupy large areas, small-scale facilities are generally built on small plots; however, the accidental scenario selection criteria in the FAQs are the same irrespective of the facility's size and complexity, which means that most small-scale LNG facilities require expensive mitigation measures to comply with the FAQs. This issue was rapidly magnified by the rapid growth of small-scale LNG in the US, as described above. The need was recognized in 2016, when the PIPES Act directed DOT-PHMSA to review and update the minimum safety standards for small-scale LNG facilities [13]. To date, however, small-scale LNG facilities under DOT-PHMSA remain subject to the same requirements as large-scale facilities.

7 The Evolution of NFPA 59A

NFPA 59A has been on a roughly three-year revision cycle since 2006, when the LNG industry really "kicked into gear". Along the way, NFPA 59A has benefited from its diversified yet balanced committee membership to adapt and evolve to keep pace with the changes in LNG markets and technologies, while taking into account the regulatory concerns. For example, DOT-PHMSA has two representatives on NFPA 59A as do other Federal and state agencies (FERC, USCG, the Railroad Commission of Texas, etc.), which ensures that changes to NFPA 59A driven by industry do not reduce public safety; conversely, the presence of special experts and industry representatives provides a practical counterpoint to changes driven by the regulators. Some of the main changes to NFPA 59A over the last 20 years are discussed in the following subsection.

7.1 Hazards and Consequence Modeling

NFPA 59A revisions up to 2001 limited the hazard analysis for facility siting to evaluating LNG pool fires in impoundments and the dispersion of LNG vapors from a "design spill", which effectively consisted of the largest flow from the LNG transfer lines. However, with several new LNG facilities being proposed, new concerns were raised during facility siting reviews as well as by environmental groups opposing the development of LNG facilities: some of these concerns focused on new modeling tools (both Computational Fluid Dynamics and integral models) being used for siting studies, while others focused on new accident scenarios (e.g., pressurized releases from piping).

In collaboration with the Fire Protection Research Foundation, the NFPA 59A rapidly addressed the modeling concerns by supporting an external effort to develop a Model Evaluation Protocol for vapor dispersion models [14], which would allow new models to be evaluated and approved for use in siting studies. The 2009 edition of NFPA 59A also began to revise the design spill table by separating requirements for containers with over-the-top withdrawal, other containers, and process areas.

A much more significant revision of the siting requirements occurred in the 2019 edition and was aimed at addressing the different hazards with potential to impact the public from large LNG liquefaction, including [9]:

- Natural gas liquefaction facilities required for LNG export are more complex and congested
- Large-scale liquefaction requires large inventories of refrigerants such as ethane, ethylene, propane, etc., at comparatively high pressures. This introduces potential for releases for flammable materials other than methane
- The use of hydrocarbons other than methane also introduces the potential for damaging explosions in the event of flammable cloud ignition in congested areas; the explosion potential is exacerbated by the higher congestion typical of liquefaction and other gas processing facilities
- Hydrogen sulfide streams may result from natural gas pretreatment, and heavy hydrocarbons are condensed and extracted during the initial gas refrigeration steps. Both sets of fluids include toxic components, which may affect the public

The new hazard analysis requirements were included in a largely reworked Chapter 5, "Plant Siting", which called for the quantitative evaluation of hazards from flammable and toxic gas or vapor dispersion, vapor cloud explosions, pool and jet fires, and fireballs. The 2019 edition also included an updated table to define the design spill from storage containers (as in previous versions) as well as from piping and other equipment (newly introduced). Requirements were also added for the evaluation and approval of consequence models for any type of hazard (not just for vapor dispersion). Finally, damage threshold criteria were specified for each hazard. All these changes allowed NFPA 59A to follow the evolution of the LNG industry to ensure that potential public safety impacts from a proposed LNG facility are properly assessed. It is important to remind the reader that the requirements in NFPA 59A represent the consensus of the technical committee, which includes both industry representatives and regulators.

7.2 Risk Assessments

As previously discussed, the siting requirements in NFPA 59A were originally developed in the 1970s, when the concept of risk assessment was in its infancy; over the following two-plus decades, as QRAs became the standard for the nuclear, petrochemical, and other industries, the U.S. LNG industry was relatively quiet, thus there was no drive to make significant changes to the Standard. This changed in the 2010s, as the rapid growth and shift to liquefaction/export highlighted the limitations of the siting requirements in NFPA 59A and in the federal regulations.

As for the other topics discussed in this paper, the NFPA 59A technical committee reacted promptly and developed a "Performance-Based Alternative Standard for Plant Siting" section that provided an alternative, risk-based approach to the long-standing, prescriptive siting requirements. The risk-based approach was initially introduced as an informative annex in the 2013 edition and then voted into the mandatory portion of the Standard as Chapter 15 in the 2016 edition. The performance-based option requires the risks to persons and property in the area surrounding the proposed LNG plant to be evaluated quantitatively, taking into account the potential hazard scenarios but also the mitigation measures incorporated into the facility design.

The alternative risk-based chapter (renumbered to Chapter 19 following a major reorganization of NFPA 59A) was further revised for the 2023 edition by including more detailed failure rate tables, derived from industry recognized databases [15,16] and assessed by a group of industry and regulatory risk experts.

7.3 Tank Types

Just as the 2006 edition of NFPA 59A first incorporated double and full containment tanks, requirements for membrane tanks – which had been used for maritime shipping of LNG since the 1960s but were first introduced for land-based LNG storage in the 2010s – were first introduced into NFPA 59A in the 2016 edition. The initial push, driven by membrane tank manufacturer GTT, consisted mainly of adapting requirements in Chapter 5, Plant Layout, and Chapter 7, Stationary LNG Storage, to explicitly include membrane tanks among the tank types listed, with ad hoc requirements where needed to differentiate between their characteristics and those of the traditional tank systems. Recognizing the unique characteristics of membrane tanks, the technical committee continued its work to more properly incorporate membrane tanks into the Standard, resulting in a thorough review and update of the Stationary LNG Storage chapter in the 2023 edition; an additional set of revisions was introduced in the 2026 revision, to eliminate duplication of requirements between NFPA 59A and ACI 376, "*Refrigerated Liquefied Gas Containment for Concrete Structures—Code Requirements and Commentary*", and API 625, "*Tank Systems for Refrigerated Liquefied Gas Storage*".

7.4 Small Scale Facilities

Prior to the issuance of the 2001 edition, small scale facilities were envisioned mainly as relatively basic installations using ASME pressure vessels as containers for LNG storage, with individual and aggregate storage capacities being the sole criterion separating small scale from other facilities. These "original" small scale facilities typically used LNG trucks to fill the ASME containers and then supplied LNG to small end users. For these designs, the main hazard to the public came from the LNG stored in the ASME containers; as such, NFPA 59A (2001) used a simple setback table for the ASME containers and their impoundment systems. Later on, as small scale LNG facilities began to be developed for "new" applications such as marine bunkering, small scale liquefaction, etc., it became apparent that the requirements in Chapter 10 did not properly align with the installation, design, and siting of these applications. For example, many of these facilities would not meet the LNG storage limits specified in Chapter 10, therefore, they would be subject the same requirements developed for large scale export facilities; the burden of meeting such requirements significantly hindered the development of small scale LNG in the US.

The 2016 PIPES Act required DOT-PHMSA to develop specific safety requirements for small-scale LNG facilities, in order to recognize the differences in risks between small and large scale facilities – for example, while small scale facilities generally occupy a smaller footprint – putting tank and equipment closer to the public – they also use much smaller amounts (if any) of heavy hydrocarbon refrigerants and produce and store smaller volumes of LNG – reducing the extent of potential hazardous consequences.

Recognizing the critical need to distinguish between the two types of facilities, the NFPA 59A committee assigned a task group to support DOT-PHMSA's effort; the effort led to the development of Chapter 17, *Requirements for Stationary Applications for Small Scale LNG Facilities*, first introduced in the 2019 edition. The new small scale chapter presented a significant evolution from the version in the current regulations; its expected adoption into code will allow small scale LNG to grow as much as the market conditions will allow.

7.5 Fire Protection

Another area where current LNG regulations have fallen behind industry standards is that of fire protection. The 2001 edition of NFPA 59A, which is currently referenced in federal regulations, specifies fire protection requirements in Chapter 9, Fire Protection, Safety, and Security. The chapter "covers equipment and procedures designed to minimize the consequences from released LNG, flammable refrigerants, flammable liquids, and flammable gases in facilities constructed and arranged in accordance with this standard. These provisions augment the leak and spill control provisions in other chapters" [2]. However, the chapter is silent on specifying actual requirements – prescriptive or performance-based – which has resulted in wide discrepancies between fire protection system designs across the industry.

In order to mitigate these discrepancies and drive the development of more consistent fire protection systems, the technical committee conducted a thorough revision and update of the fire protection requirements for the 2026 edition, introducing the requirement to provide a quantitative assessment of the system's performance, consistent with established codes and standards and acceptable to the authority having jurisdiction. Fire and gas detectors are now required to be located in accordance with a documented performance-based analysis in order to provide a more consistent design approach for these devices in the LNG industry. The standard clarifies which requirements apply to facilities when in-kind replacements are made in order to encourage maintainability, reliability, and safety at LNG facilities.

Stressing the critical importance of fire protection systems to an LNG facility, the revised fire protection requirements (now in Chapter 16) also include a new requirement to review and update, if necessary, each facility's fire protection evaluation every 2 years.

8 Conclusions

This paper reviewed the evolution of the LNG industry in the United States, focusing on the last 20+ years, and described how NFPA 59A evolved over time to keep abreast of changes in the LNG industry. The constant evolution of NFPA 59A allowed it to keep current with changes in technology, relevant hazards, and process safety practices (e.g., QRA, fire detection). On the opposite end of the spectrum, DOT-PHMSA's regulations have remained unchanged for over 20 years, which has created numerous issues when project developers try to reconcile new technologies with dated and possibly irrelevant requirements. DOT-PHMSA has tried to bridge the gap in terms of facility siting by creating a Frequently Asked Questions (FAQ) webpage to guide developers through its evolving set of requirements. However, the regulation-by-website approach is neither lawful (it does not provide the public with an opportunity to comment on new or changed requirements before they are enforced) nor practical for the developers of multi-billion dollar facilities (the FAQ page was updated at random intervals and without notification to interested parties, causing numerous instances of confusion), nor complete as it only addresses siting requirements while leaving other regulatory areas unaddressed. In fact, some projects may need to comply with up to 4 versions of NFPA 59A: for example, DOT-PHMSA requires the 2001 edition of NFPA 59A with some requirements also tied to the 2006 edition, USCG requires the 2019 edition, and State fire marshals incorporate different versions of NFPA 59A depending what is incorporated into each State's building codes, and finally many projects follow current good practice and thus design to the most recent version of NFPA 59A (2026).

While the upcoming revision of DOT-PHMSA's regulations presents an opportunity to reconcile regulatory requirements with current best practices, it will be critical for federal agencies to commit to more frequent updates of their regulations going forward, or the same problems are bound to reoccur in the near future.

9 References

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