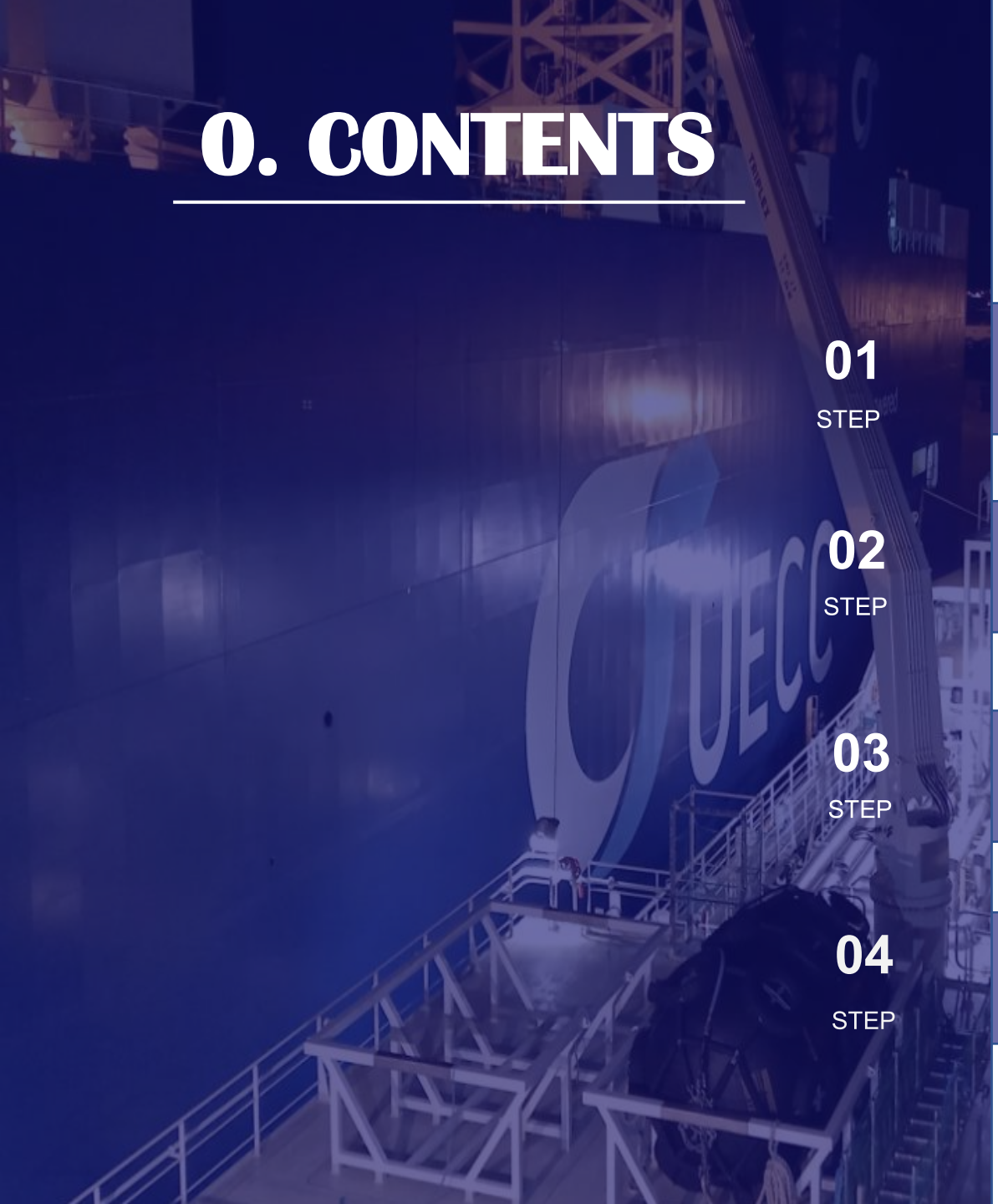
(Safety) LNG as marine fuel:

Proposals for safe LNG Bunkering industry

TEAM Lighthouse

LNG: the Best Future Fuel



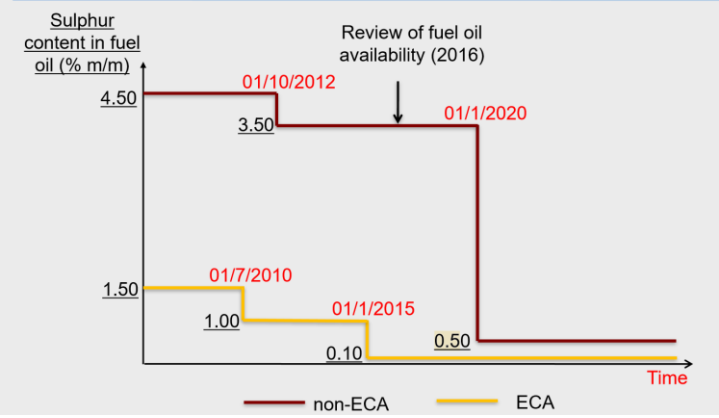
0. CONTENTS

1. BACKGROUND

- IMO 2020
- LNG-fuelled ships
- LNG bunkering facilities

IMO 2020: Emission Regulation Enforcement

SO_x Emission Regulation

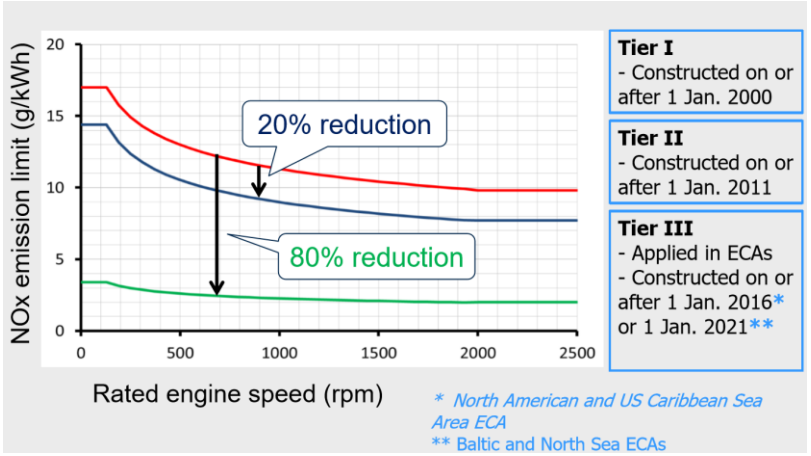


MARPOL Annex VI Regulation 14

Outside the ECA	Inside the ECA
4.50% m/m prior to 1 January 2012	**1.50% m/m** prior to 1 July 2010
3.50% m/m on and after 1 January 2012	**1.00% m/m** on and after 1 July 2010
0.50% m/m on and after 1 January 2020	**0.10% m/m** on and after 1 January 2015

→ Significant Enforcement of So_x Regulation outside the ECA

NO_x Emission Regulation



→ NO_x Emission Limit decreased by 80% since 2000 (Tier I → III) (Jan 2016)

Source : MARPOL Annex VI Regulation 13 & 14

Alternatives to satisfy IMO 2020

1. Low Sulfur Fuel

- Compatible with existing propulsion systems
- Possibility of a surge in oil prices
- Quality assurance issues

→ ***Inadequate supply to be universal fuel***

2. Scrubber

- Environmental-Friendly
- Costly
- Possible additional regulations

→ ***Currently a prevailing solution, but unsustainable***

The Best Alternative: 3. LNG-fuelled Ships

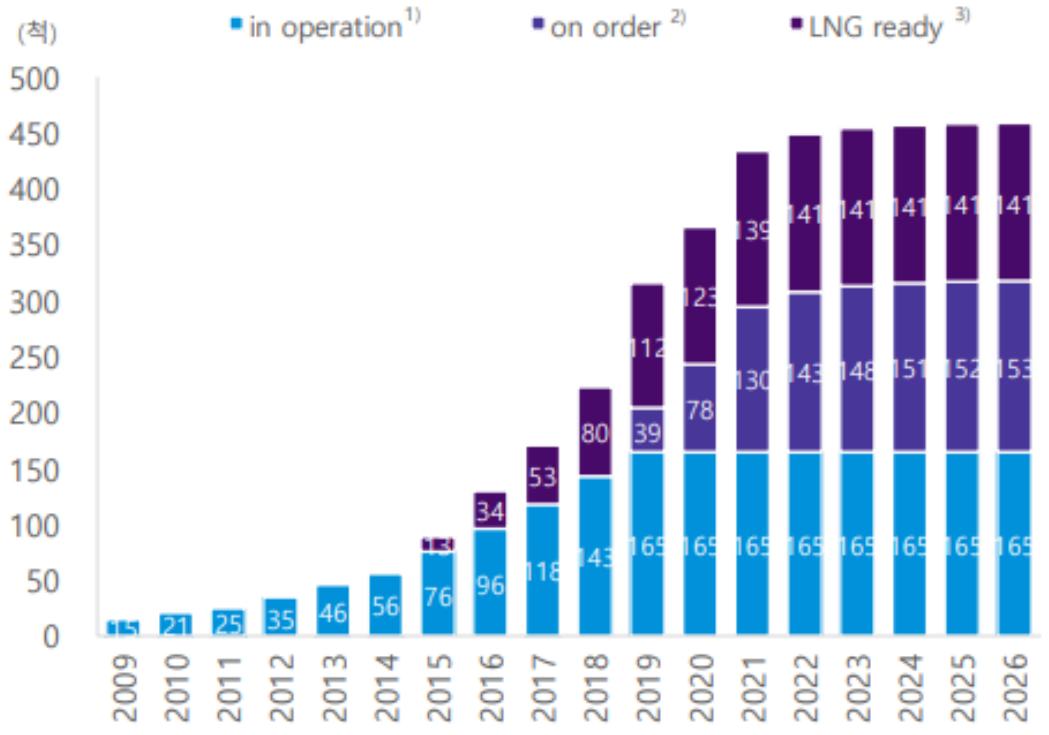
LNG fuel…

- ✓ produces remarkably low amount of air pollutants
- ✓ complies with IMO's standards for NO_X/SO_X Emissions
- ✓ reduces Carbon Dioxide by 30%
- ✓ has a good prospect: LNG infrastructure is expected to be expanded in the future

→ **LNG fuel has** the ***highest*** possibility of ***universalization.***

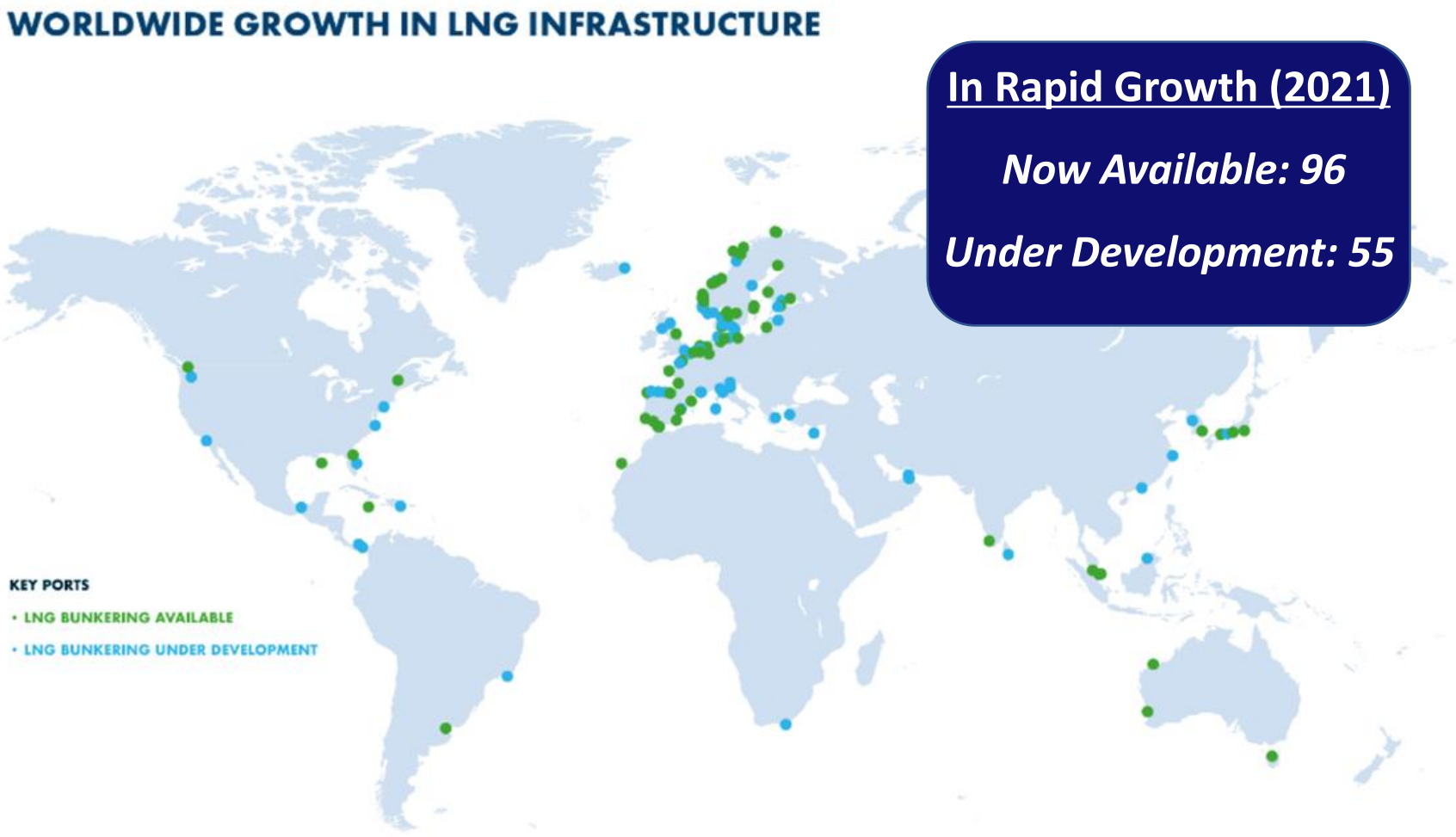
The future of LNG-fuelled ships

Trends and prospects of global LNG propulsion vessels



Source : DNV GL Alternative Fuels insight portal

LNG bunkering facilities around the world



In Rapid Growth (2021)

Now Available: 96

Under Development: 55

Source : SEA/LNG

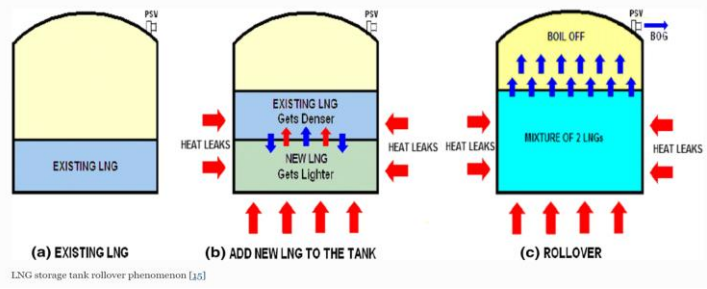
2. PROBLEM

- **Drawbacks of LNG**
- **Current solutions**

LNG as marine fuel: the drawbacks

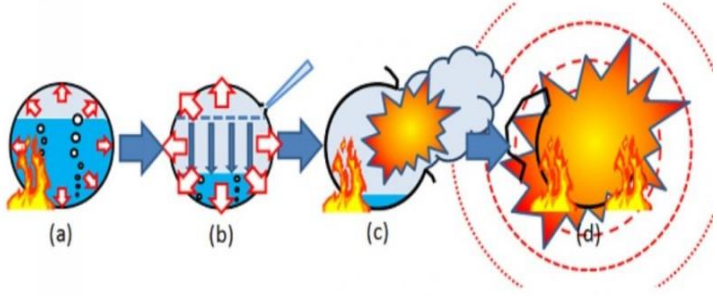
1. **Insufficient fueling systems (bunkering infrastructure)**

2. **Rollover phenomenon**



LNG storage tank rollover phenomenon [15]

3. **Possible BLEVE**



4. **Potential leak of LNG**

CCC 3/INF.13
Annex, page 2

1. Introduction

For ships using LNG as a fuel, LNG bunkering is an unavoidable process. The most established method of LNG bunkering is to transfer LNG from an LNG terminal to a receiving ship in a similar way as LNG cargo is loaded. However, lack of terminal infrastructure has encouraged several alternative methods to emerge, such as using LNG tank lorries, LNG feeder ships or portable LNG tanks [1][2]. Since 2000 when the world's first LNG-fuelled ship, the MV **Glutra**, was put into service, small to medium scale LNG bunkering has taken place using some of these alternative methods by a total of 48 LNG-fuelled ships [3][4].

LNG bunkering requires careful attention to safe operations as it entails potential risks pertaining directly to the cryogenic liquid transfer and vapour returns, much more so than the conventional liquid fuel bunkering. According to a report of Norwegian Maritime Authority [5], four accidents associated with LNG spill have been reported – one of which led to an injury of a crew member on his hands and legs due to cryogenic burn. Moreover, in large scale LNG bunkering operations for large ocean going ships, significant uncertainties associated with massive accidental LNG release are present. In view of the possibly catastrophic consequences of such accidents, the risks associated with LNG bunkering merit careful study.

3.3 *Consequence Analysis*

As discussed earlier in scenario analysis, ignition of leaked fuel can lead to several types of accidents depending on a variety of factors: pool fire, flash fire, jet fire and explosion. The leak rates estimated for various hole sizes are presented in table 3. Using empirical models, the impact of each consequence is evaluated. For this case study, the following consequence models, which are generally applied to investigating the impact of fire and explosion associated with LNG accidents, are adopted: TNO model with TNO 7 [16] for explosion, Cook model [17] for jet fire and Briggs model [18] for flash fire. A normal weather condition with the stability class D and a wind speed of 5 m/s is assumed [3]. Detailed methodologies applied to consequence analysis are described in Consequence Analysis section of the appendix.

IMO documents CCC3/INF.13 regarding the problem

Maritime Industry Actions

01 **Designation of safety exclusion zone**
(controlled zone)

02 **Facilitation of PPE/PIC**
(Personal protective equipment /Person in charge)

03 **Different regulations according to weather conditions**

04 **Emergency shutdown system**
(ESD system)

Safety regulations dealing with LNG bunkering

01 **IMO (2016) IGC Code**

International Code for the Construction and Equipment for Ships Carrying Liquefied Gases in Bulk

02 **IMO (enters into force 01 Jan 2017) IGF Code**

International Code of Safety for Ships Using Gases or Other Low-flashpoint Fuels

03 **IMO (2010) STCW**

International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978, as amended and Manila Amendments

Are these actions enough?

Although there are various regulations, the absence of the standard or obligation of the regulations had caused many incidents.

LNG leakage

Port of Barcelona, 2015: LNG Vapor released from the LNG Tanker the Fuwairit.

Isabella, 1985: 35,500 m3 LNG tank overflowed while vessel was being unloaded, causing a crack to the deck plate.

Collided LNG vessels

March 26, 2019: The Shipping Corporation of India LNG carrier collided with a very large crude carrier at a Fujairah anchorage in the **United Arab Emirates.**

May 2, 2011: he crane operator caused a collision with the valves of three of the cylinders.

Source : Image of port Barcelona, 2015

Strategic Direction

The necessity for enforcement and standardization of safety regulations.

Strategic Direction (SD -2)
Integrate new technologies into the regulatory framework

LNG : Environment-friendly

Strategic Direction (SD -3)
Respond to climate change

TDCs
Propulsion systems and alternative fuels

3. Solution

Standardizing safety regulations

- Short-term: Amendments to the IGF code
- Long-term: A working group under CCC

Overview

Problem → **Solution**

Danger in LNG bunkering due to <u>unstandardized safety regulations</u>

To standardize safety regulations

1. Short term

Amendments to the IGF code

2. Long term

Organization of Working Group in CCC

Solution 1. Make amendments to the IGF Code

International Code of Safety for Ships Using Gases or other Low-Flashpoint Fuels

(RESOLUTION MSC.391(95))

INTERNATIONAL CODE OF SAFETY FOR SHIPS USING GASES
OR OTHER LOW-FLASHPOINT FUELS (IGF CODE)

CONTENTS

Solution 1. Make amendments to the IGF Code

◆ Proposal for Amendments

1. Subdivision of the Safety Exclusion Zone (Controlled Zone)
2. Accurate guidelines for the subdivision regarding various factors
3. Safety guidelines for the personnel (Personal Protective Equipment)

IGF Code **12. Explosion Prevention**

12.4 Regulations on area classification

12.4.1 Area classification is a method of analysing and classifying the areas where explosive gas atmospheres may occur. The object of the classification is to allow the selection of electrical apparatus able to be operated safely in these areas.

12.4.2 In order to facilitate the selection of appropriate electrical apparatus and the design of suitable electrical installations, hazardous areas are divided into zones 0, 1 and 2. See also 12.5 below.

12.4.3 Ventilation ducts shall have the same area classification as the ventilated space.

IGF Code **12. Explosion Prevention**

12.5 Hazardous area zones

12.5.1 Hazardous area zone 0

This zone includes, but is not limited to the interiors of fuel tanks, any pipework for pressure-relief or other venting systems for fuel tanks, pipes and equipment containing fuel.

12.5.2 Hazardous area zone 1

This zone includes, but is not limited to:

.1 tank connection spaces, fuel storage hold spaces and interbarrier spaces;

.2 fuel preparation room arranged with ventilation according to 13.6;

.3 areas on open deck, or semi-enclosed spaces on deck, within 3 m of any fuel tank outlet, gas or vapour outlet, bunker manifold valve, other fuel valve, fuel pipe flange, fuel preparation room ventilation outlets and fuel tank

(…)

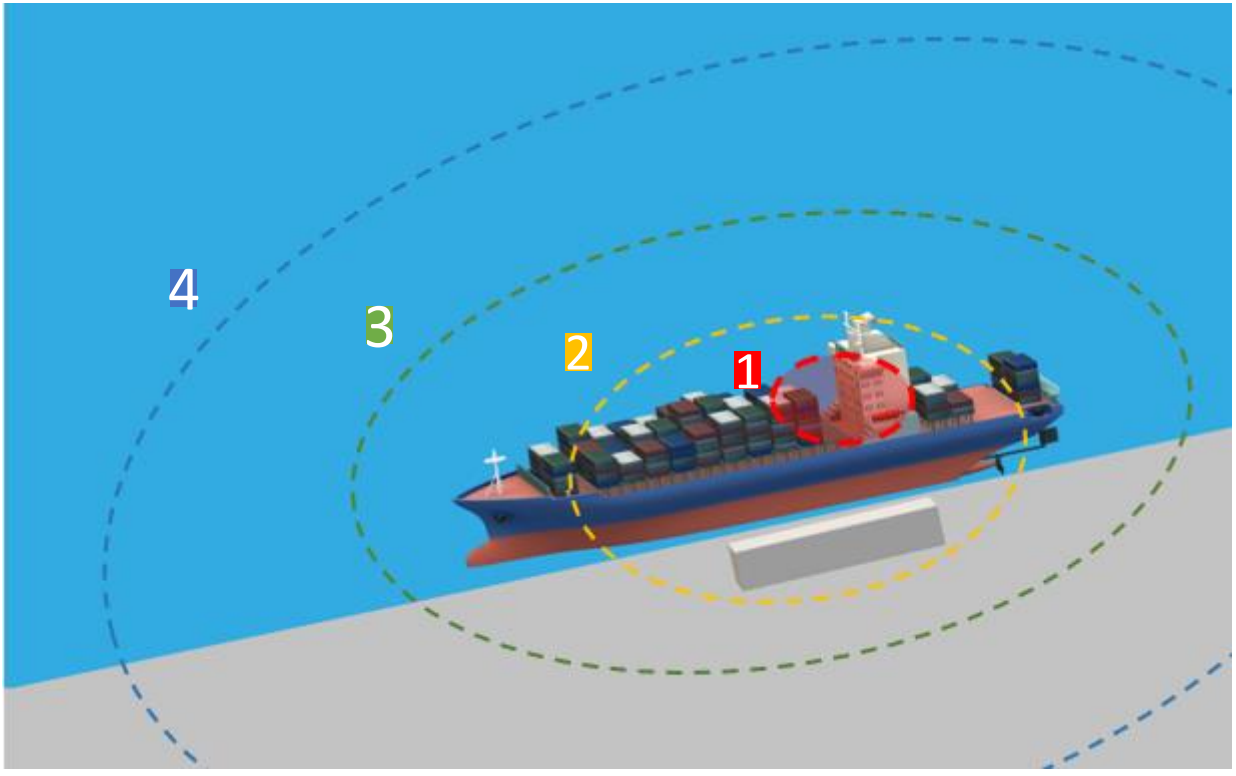
Solution 1-1. Subdivision of the Safety Exclusion Zone

Hazardous area zone: an area in which an explosive gas atmosphere is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of equipment. (RESOLUTION MSC.391(95))

Safety Zone: three-dimensional envelope of distances where the majority of leak events occur and having a potential for a leak of LNG (ISO/TS 18683:2015)

Monitoring/Security Zone: a three dimensional space where activities need to be identified and monitored to ensure that they do not affect the safety on the Safety Zone. (© Society for Gas as a Marine Fuel)

Solution 1-1. Subdivision of the Safety Exclusion Zone



Hazardous area Zone

Monitoring/Security Zone

Safety Zone

Safety Exclusion Zone

Solution 1-1. Subdivision of the Safety Exclusion Zone

All LNG-fuelled ships shall concern the following standard of Safety Exclusion Zones(Controlled Zones):

IGF Code **12. Explosion Prevention**

12.5 Safety Exclusion Zone

12.5.1 level 1 Hazardous area zone: an area in which an explosive gas atmosphere is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of equipment. Hazardous area should be always present, but can be modified according to technical advances or safety practices.

12.5.1.1 Hazardous area zone 0

12.5.1.2 Hazardous area zone 1

12.5.2 level 2 Safety Zone: an area in which possibility of LNG leakage is still present but mostly in exceptional circumstances. It should be larger than the Hazardous area zone. In this area, non-essential people should be inhibited, PPE should be strictly used and PIC should always be present. The area shall be temporary but it should be defined before each bunkering process.

12.5.3 level 3 Monitoring/Security Zone: a three dimensional space where activities need to be identified and monitored to ensure that they do not affect the safety on the Safety Zone. It should be larger than the Safety Zone.

12.5 Safety Exclusion Zone

12.5.1 level 1 Hazardous area zone: an area in which an explosive gas atmosphere is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of equipment. Hazardous area should be always **present**, but **can be modified according to technical advances or safety practices.**

12.5.1.1 Hazardous area zone 0

12.5.1.2 Hazardous area zone 1

12.5.2 level 2 Safety Zone: an area in which possibility of LNG leakage is still present but mostly in exceptional circumstances. It should be **larger than the Hazardous area zone.** In this area, non-essential people should be inhibited, PPE should be strictly used and PIC should always be present. The area shall be **temporary,** but it should be defined before each bunkering process.

12.5.3 level 3 Monitoring/Security Zone: a three-dimensional space where activities need to be identified and monitored to ensure that they do not affect the safety on the Safety Zone. It should be **larger than the Safety Zone.**

Solution 1-2. Accurate guidelines for the subdivision

IGF Code **12. Explosion Prevention**

12.5 Hazardous area zones

12.5.2 Hazardous area zone 1

This zone includes, but is not limited to:

.1 tank connection spaces, fuel storage hold spaces and interbarrier spaces;

.2 fuel preparation room arranged with ventilation according to 13.6;

.3 areas on open deck, or semi-enclosed spaces on deck, within 3 m of any fuel tank outlet, gas or vapour outlet, bunker manifold valve, other fuel valve, fuel pipe flange, fuel preparation room ventilation outlets and fuel tank openings for pressure release provided to permit the flow of small volumes of gas or vapour mixtures caused by thermal variation;

.4 areas on open deck or semi-enclosed spaces on deck, within 1.5 m of fuel preparation room entrances, fuel preparation room ventilation inlets and other openings into zone 1 spaces;

(…)

12.5.3 Hazardous area zone 2

12.5.3.1 This zone includes, but is not limited to areas within 1.5 m surrounding open or semi-enclosed spaces of zone 1.

-> Subdivision of the Safety Exclusion Zone according to various factors

Solution 1-2. Accurate guidelines for the subdivision

IMO INTERNATIONAL MARITIME ORGANIZATION

E

SUB-COMMITTEE ON CARRIAGE OF CARGOES AND CONTAINERS
3rd session
Agenda item 3

CCC 3/INF.13
1 July 2016
ENGLISH ONLY

AMENDMENTS TO THE IGF CODE AND DEVELOPMENT OF GUIDELINES FOR LOW-FLASHPOINT FUELS

Evaluation of safety zone for LNG bunkering station for LNG-fuelled ships

Submitted by the Republic of Korea

SUMMARY

Executive summary:	This document provides information on the result of a research project regarding potential risks of LNG bunkering and key factors in determining the extent of the safety exclusion zone of LNG bunkering station through case studies
Strategic direction:	5.2
High-level action:	5.2.1
Output:	5.2.1.2
Action to be taken:	Paragraph 2
Related document:	IGF Code (resolution MSC.391(95))

Introduction

1 In the annex to this document, the Republic of Korea presents the findings of a research project as a reference for establishing the safety exclusion zone of LNG bunkering station.

Action requested of the Sub-Committee

2 The Sub-Committee is invited to note the information provided in the annex.

***

https://edocs.imo.org/Final Documents/English/CCC 3-INF.13 (E).docx

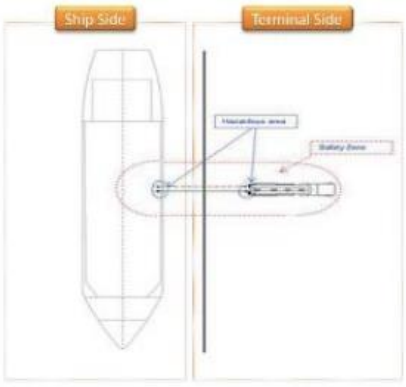


Figure 1 Illustration of a safety exclusion zone for LNG bunkering [2]

On the other hand, the safety exclusion zones for ships have yet to be studied probabilistically. As a result, sets of quantified guidelines for establishing the safety exclusion zone of LNG bunkering station for ships have not been firmly established as yet.

Source : CCC 3/INF.13

Solution 1-2. Accurate guidelines for the subdivision

ISO/TS 18683(ISO 2015)

1. This standard based on the worst-case scenario or probabilistically using quantitative risk assessment.
2. It is usually based on an extreme event regardless of the probability of its occurrence. The determination of the 'extreme' event is somewhat arbitrary as well

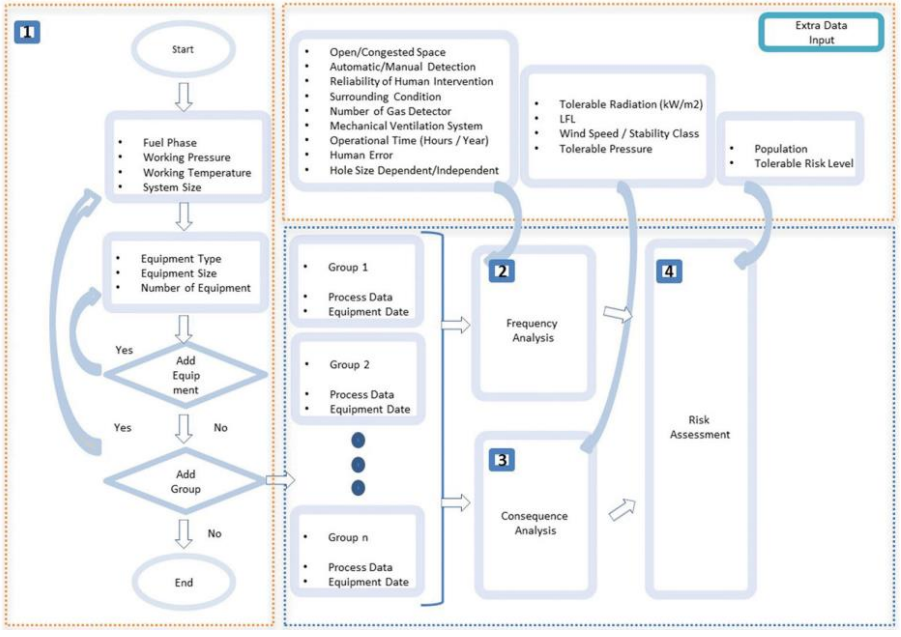
DNV GL guideline

1. DNV GL only focuses on the consequence of flash fire
2. DNV GL guideline does not fully consider the frequency of LNG bunkering

Various factors

- Ship geometry
- Wind speed, direction (Weather)
- Leakage rate(hole size)
- Leak frequency
- •
- •
- •
- ETC.

Integrated quantitative risk assessment



Source : Evaluation of safety exclusion zone for LNG bunkering station on LNG-fuelled ship(2017)

Solution 1-2. Accurate guidelines for the subdivision

IGF Code **12. Explosion Prevention**

12. 4 Regulations on area classification

12.4.4 In order to prevent unexpected safety accident during fueling up the ship (ship to ship, truck to ship, station to ship … etc.), safety exclusive zone allow LNG bunkering to operate more safely. See also 12.5 below

12.5 Safety Exclusion Zone

12.5.4 This zone shall be determined based on the methods below:

.1 The Safety Exclusion Zone shall never be zero and never be less than the hazardous areas and/or the minimum distance defined by authorities from any part of the bunkering installation.

.2 The latest research results should be continuously reflected by CCC

.3 Integrated computing program should be applied

12.5.5 This zone shall be determined based on the factors below:

.1 Ship geometry

.2 Wind speed, direction (Weather)

.3 Leakage rate (Hole Size)

.4 Leak frequency

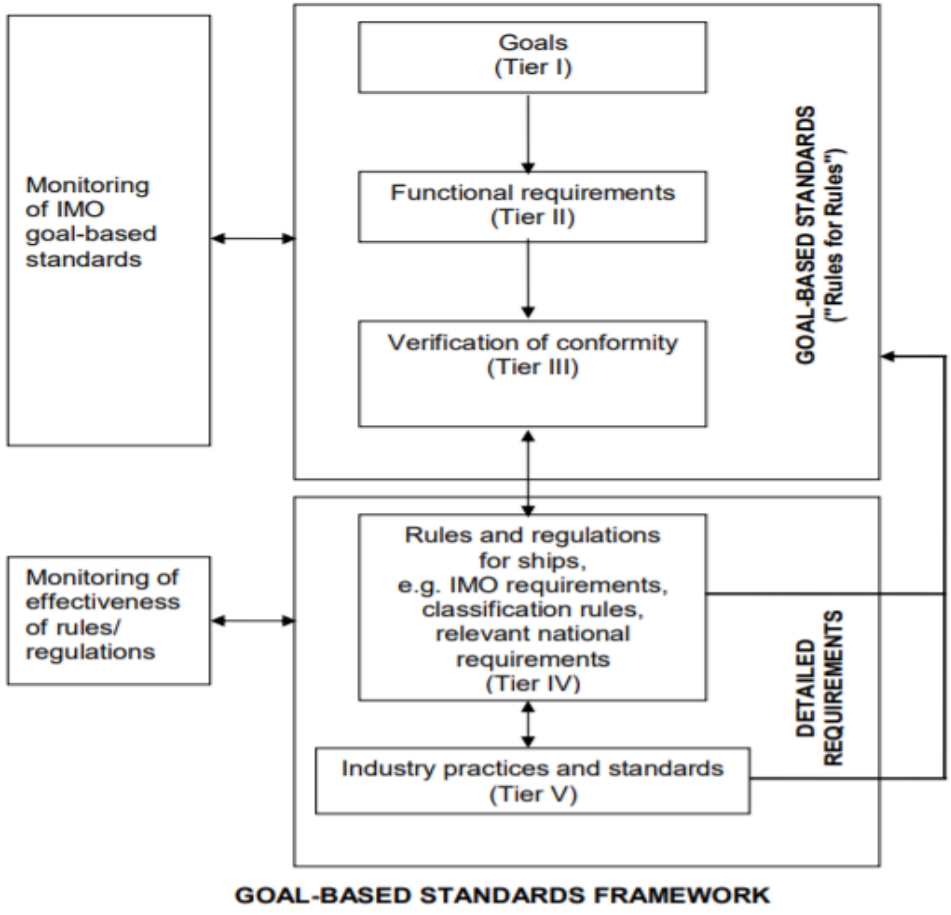
.5 Etc.

→ ***New provisions for the determination of the Safety Exclusion Zone***

Solution 1-2. Accurate guidelines for the subdivision

New factors to determine safety exclusion zone

-> use **GBS**(goal-based-standard)



GOAL-BASED STANDARDS FRAMEWORK

Pros of using GBS

→ Specific enough in order not to be open to differing interpretations

→ Broad, over-arching safety, environmental and/or security standards.

Source : IMO Documents MSC.1/Circ.1394/Rev.2

Solution 1-3. Safety Guidelines for the personnel

IGF Code **18.4 Regulations for bunkering operations**

18.4.6 Conditions for transfer

18.4.6.1 Warning signs shall be posted at the access points to the bunkering area listing fire

safety precautions during fuel transfer.

18.4.6.2 During the transfer operation, personnel in the bunkering manifold area shall be limited to essential staff only. All staff engaged in duties or working in the vicinity of the operations shall wear appropriate personal protective equipment (PPE). A failure to maintain the required conditions for transfer shall be cause to stop operations and transfer shall not be resumed until all required conditions are met.

→ ***the need for specific provisions regarding Personal Protective Equipment***

Solution 1-3. Safety Guidelines for the personnel

Table 4.12 - Guidelines on LNG Bunkering – Documents comparison

	ISO TS 18683	EN ISO 20519	DNV GL RP	BV guidelines	ABS guidelines	SGMF guidelines
Material Problems (MP)						
personal protective equipment (PPE)	x	x	x	-	x	x

ISO/TS 18683(ISO 2015)

8.5.3. Personnel shall use PPE (personnel protective equipment) as appropriate for the operations.

EMSA Guidance on LNG Bunkering to Port Authorities/Administrations

5.7.4 Port Roles and Responsibilities in LNG Bunkering

Confirmation of Hazardous Zone Surrounding the LNG bunkering manifold connections a hazardous area shall be defined at the responsibility of the BFO and RSO. Port Authorities should confirm by inspection that all personnel working and equipment used inside Hazardous Zones is adequately certified for the area in consideration. PPE and EX-proof material should be used. Even though a responsibility of the parties involved, the maintenance of the permitting should be based on periodic confirmation by PAAs that all safety procedures and measures are well kept in place and ensured by parties involved.

Source: EMSA Guidance on LNG Bunkering to Port Authorities/Administrations

Solution 1-3. Safety Guidelines for the personnel

<Safety manual on LNG bunkering procedures for the Port of Helsinki>

5.3.3 *Personal Protective Equipment (PPE)*

All personnel involved in handling of LNG and cryogenic equipment shall use appropriate personal protective equipment (PPE) for the LNG bunkering operation. It shall be ensured that all personnel is trained in the proper use of PPE.

- The PPE shall include but not be limited to:
- Protective cryogenic gloves
- Tightly fitting safety googles and safety face shield with side protection
- Clothing should be fully body comprehensive, flame resistant, cryogenic retardant and have visibility markings.
- Safety shoes
- Safety helmet
- Life jacket must be worn when working on berths or piers or where there is a risk of falling into the water.
- Hearing protections (to be easily accessible)

Source : Safety manual on LNG bunkering procedures for the Port of Helsinki

Solution 1-3. Safety Guidelines for the personnel

IGF Code **19. Safety Guidelines for the Personnel**

19 Personnel Safety Regulations

19.1 Goal

The goal of this chapter is to ensure the safety of the personnel by regulating PPE(Personal Protective Equipment) and PPC(Personal Protective Clothing).

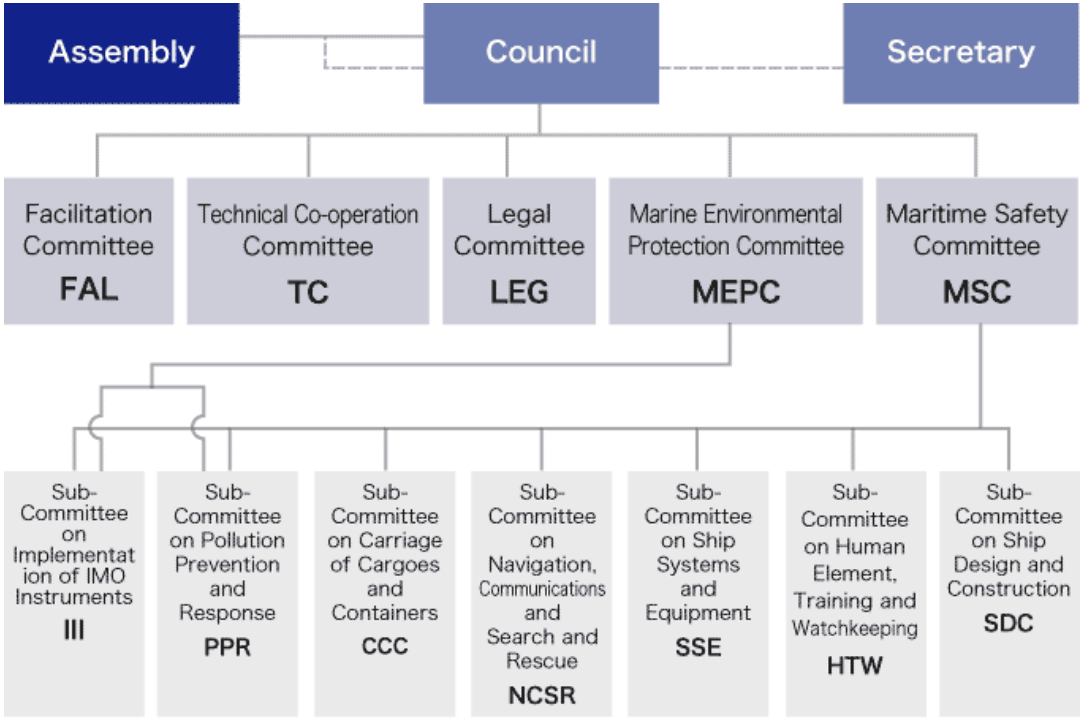
19.2 Regulations for PPE

19.2.1. All LNG-fuelled ships shall ensure the safety of the personnel by obligating the following PPE:

.1 Protective cryogenic gloves
.2 Tightly fitting safety googles and safety face shield with side protection
.3 Clothing should be fully body comprehensive, flame resistant, cryogenic retardant and have visibility markings.
.4 Safety shoes
.5 Safety helmet
.6 Life jacket must be worn when working on berths or piers or where there is a risk of falling into the water.
.7 Hearing protections (to be easily accessible)

Solution 2. Ensuring future modification of safety guidelines

Our proposal: To establish a working group under CCC to ensure future modification of the regulations



Sub-Committee on Carriage of Cargoes and Containers(CCC) reviews IGF&IGC code.

Working group specializing LNG bunkering safety regulations under CCC

Source : Structure of IMO(ClassNK)

Solution 2. Ensuring future modification of safety guidelines

- **Why do we need a specializing working group?**

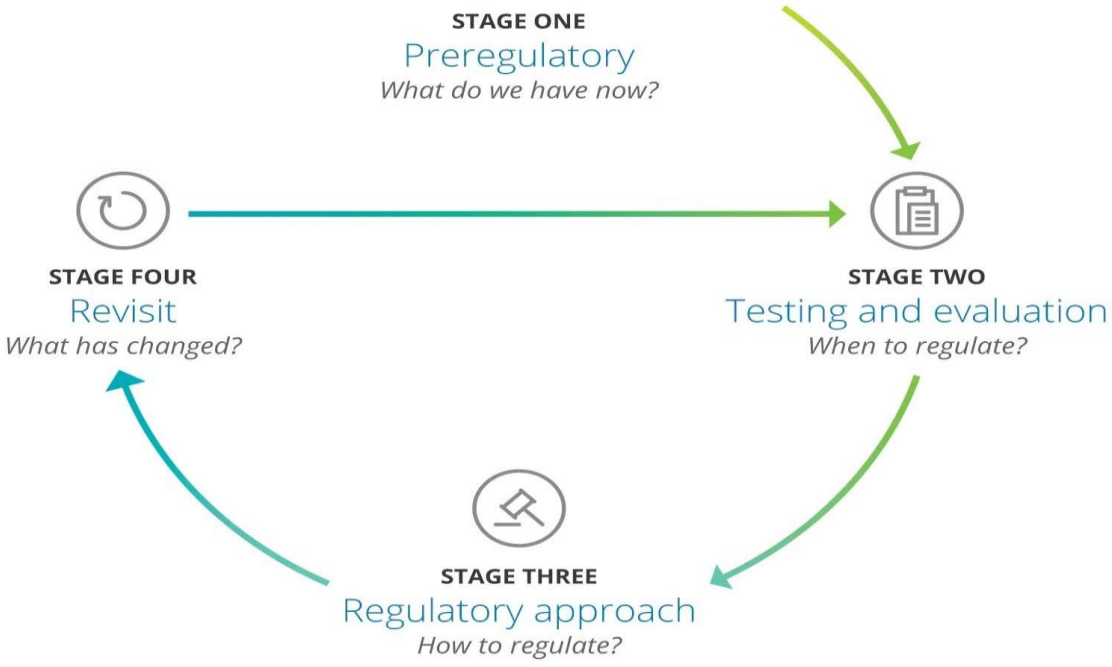
01 **Regulations needs to be periodically amended**
(technological advances, consumer preferences...etc.)

02 **Rigid regulations can be an obstacle to the industry**
(may be a strain for bunkering industry)

03 **CCC's main work is not about IGF&IGC code**
(According to IMO website, they mainly focus on IMSBC&IMDB code.)

Solution 2. Ensuring future modification of safety guidelines

Regulation needs to be amended periodically



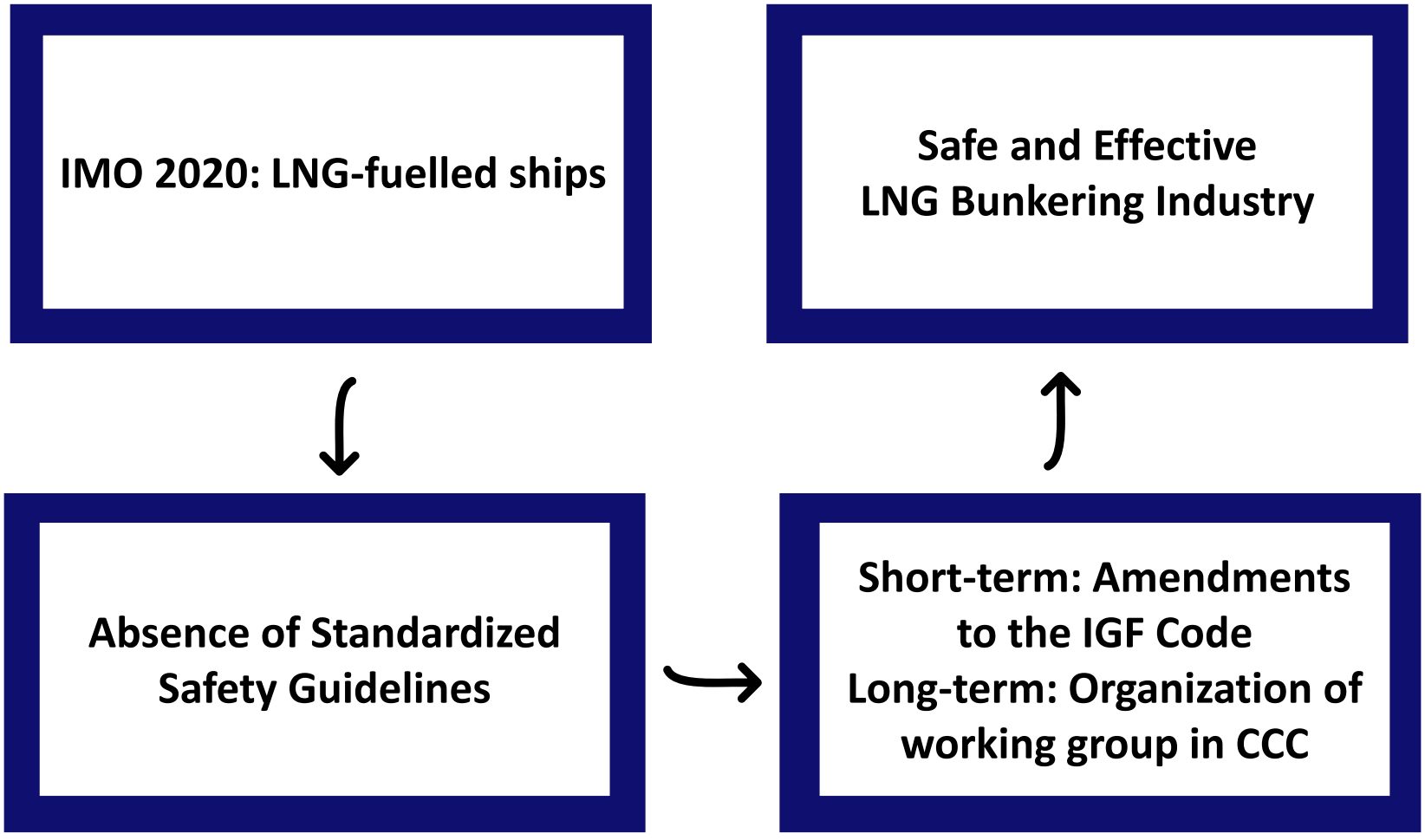
These reviewing of LNG bunkering safety regulations should be done in every 2 years by our new working group under CCC.

Source : Model for government regulations Given by Deloitte.

4. CONCLUSION

- **Summary**
- **Expected Results**

Summary


IMO 2020: LNG-fuelled ships
Absence of Standardized Safety Guidelines
Short-term: Amendments to the IGF Code
Long-term: Organization of working group in CCC
Safe and Effective LNG Bunkering Industry

Expected Results

1. Standardized guidelines on the Safety Exclusion Zone will be made and widely used within the Member Countries.

2. The development of LNG Bunkering infrastructure will be promoted worldwide.

3. Potential safety hazards concerning LNG Bunkering will be prevented.

Further Actions: Zero-Carbon Fuel

"The absence of standardized regulations

is a common problem for any new normal."

References

[1] Third IMO GHG study, 2014
[2] MARPOL Annex VI Regulation 14
[3] “Marine fuel sulfur content limit." www.adlittle.com/en/HighSulphurFuels. Web. April 2018.
[4] MARPOL Annex VI Regulation 13
[5] IMO NOx limits
[6] DNV GL Alternative Fuels insight portal
[7] IMO documents CCC3/INF.13
[8] https://www.imo.org/en/MediaCentre/MeetingSummaries/Pages/CCC-Default.aspx
[9] ClassNK
[10] IGF code
[11] Safety manual on LNG bunkering procedures for the Port of Helsinki
[12] EMSA Guidance on LNG Bunkering to Port Authorities/Administrations
[13] ABS. 2014. Bunkering of Liquefied Natural Gas-fuelled Marine Vessels in North America. Houston, TX: ABS.
[14] Evaluation of safety exclusion zone for LNG bunkering station on LNG-fuelled ships
[15] A study on factors affecting the safety zone in ship-to-ship LNG bunkering

TEAM Lighthouse