LNG Floating Storage (FSU) and Regasification Units (RGU)

THE EVALUATION OF SEVESO III SAFETY REPORTS, EMERGENCY PLANS & SAFETY MANAGEMENT SYSTEMS

THE EXPERIENCE WITH THE LNG PROJECT IN DELIMARA MALTA

MJV CYPRUS 26-28 September 2017

CHE.RE.E
CHEMICALS REGULATIONS ENFORCEMENTS & INSPECTIONS

Dr. George Papadakis
Technical University of Crete, School of Production Engineering & Management

Advisor of Malta SEVESO Authority

- Since 2013, on the Evaluation of Safety Reports and in SEVESO Inspections for all SEVESO establishments in Malta ;

For the Delimara LNG project :

- **2014, on the Evaluation of Preliminary Safety Reports and QRA studies (Conceptual and basic Design) for Land Use Planning purposes;**
- **2015-2016, on the Evaluation of all "SEVESO" Reports (FEED to as Built) for the purposes of the Operation Permit;**
- **2017, on the Inspections of LNG project (FSU and RGU)**

Past Experience on Industrial Risk and SEVESO implementation

- *Research on LNG storage safety since 1985 (UMIST UK)*
- *1993 -2000, Eur. Commission (national detached expert in the MAHB, JRC) on SEVESO Directive as Secretary of the EC WGs for the development of EC Guidelines on Seveso II Safety Reports (A. Amendola- G. Papadakis) and Seveso Inspections (G. Papadakis – S. Porter); 2003 – 2006 member of EC WG (DG TREN) on Major Accidents Hazards from Pipelines (Natural Gas) - Safety of Oil & Gas Pipelines in the EU*
- *Since 1999: SEVESO advisor of SEVESO (COMAH) Authorities in Greece and Cyprus; Risk Assessment, QRAs, LUP studies in many countries (refineries, fuel depots, NG grids, etc).*
- *Since 2000: Lecturing – Research on Industrial Risk in the Technical Univ. of Crete (School of Production Engineering and Management, Lab of Ergonomics and Safety).*

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Chemicals Regulations Enforcement & Inspections – Building Authority Capacity for REACH/CLP and SEVESO III Compliance

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Department of Labour Inspections CYPRUS
Ministry of Labour, Welfare, and Social Insurance

ΕΛΛΗΝΙΚΗ ΔΗΜΟΚΡΑΤΙΑ

ΑΑΔΕ
Ανεξάρτητη Αρχή Δημοσίων Εσόδων

General Directorate of
General Chemical State Laboratory
Directorate of Energy, Industrial and Chemical Products
Independent Authority for Public Revenue GREECE

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- **Searching for synergies with JRC, MAHB and MJV and National Enforcement Authorities on activities of common interest related to REACH/CLP and SEVESO Inspections.**

- **Proposal for a common Workshop in Crete Greece within the next 2 years.**

Scope of Advisory Work
Malta LNG project (Delimara)

- To **EVALUATE the COMPLIANCE of OPERATORS with the requirements of SEVESO III Directive** on the Control of Major Accident Hazards (transposed to Maltese LN 179/2015) and with the National Policies according to Risk Acceptance Criteria;

- **Ultimate Goal is to assess completeness, adequacy and credibility of all safeguards foreseen** in the Safety Reports to prevent, control and mitigate any major accident effects on the population in the vicinity of the new SEVESO establishment.

- To verify and monitor implementation of safeguards through SEVESO Inspections: Site Visits & Inspection report during and after commissioning of operations (2017 onwards -)

SEVESO III regulatory requirements and issuing of Permits for Construction or Operation

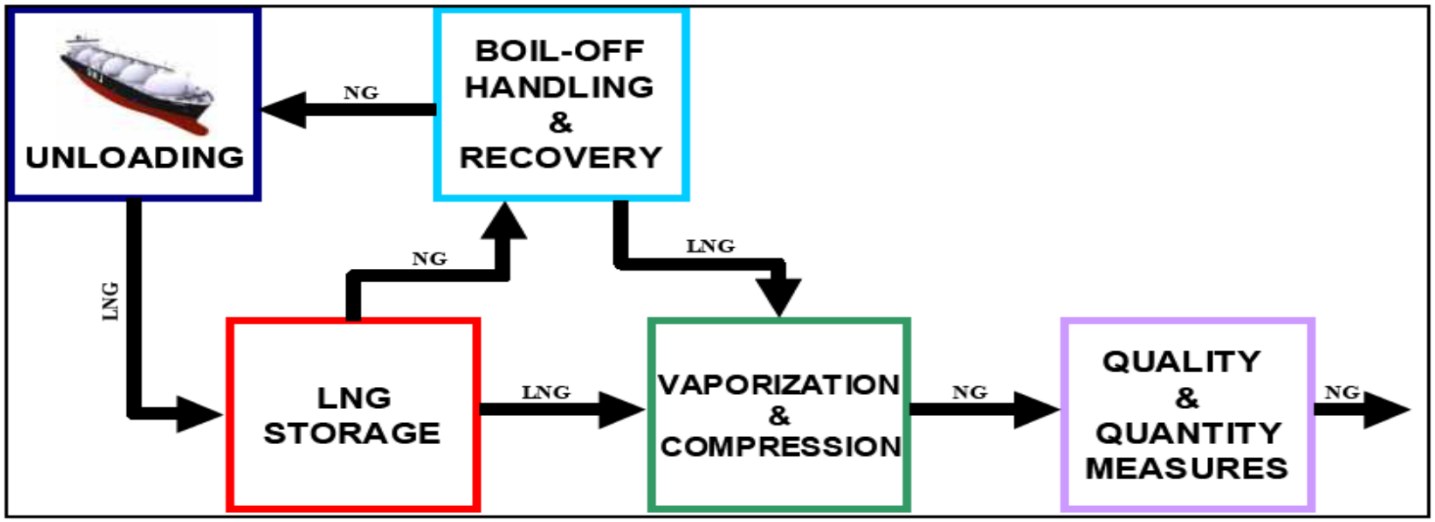
- **Safety Report : SEVESO III (2012/18/EU) art .10 – Transposed into Maltese LN 179/2015 reg. 8**
  - ✓ **Contents** : **par. 1 (a)** " .. demonstrating that a Major Accident Prevention Policy (MAPP) and Safety Management System (SMS) …**have been put into effect**…" **par. 1 (b)** " .. demonstrating that major-accident **hazards** and **possible major-accidents** have been **identified** and **necessary measures** have been **taken to prevent such accidents** and to **limit their consequences** for human and the environment" **par. 1 (c)** " .. that adequate safety and reliability have been taken into account in the **design, construction, operation** and maintenance..**linked to major-accident hazards**.." **par. 1 (d)** ".. demonstrating that internal **emergency plans** have been **drawn up** and **supplying information to enable external EP to be drawn up**"
  - ✓ **par. 3 (a) Safety Report** & **Internal Emergency plan** sent to authorities "**..** For new establishments **..a reasonable period of time prior to the start of construction or operation ..**"
- **Prohibition of Use art. 19 : (reg. 15 , par. 1 LN 179/2015)** " ..prohibit bringing into use any establishment …where measures are **seriously deficient**. To this end, … necessary actions **identified in the inspection report**."
- In the Directive there is **NO direct link between the Safety Report (operator/authority obligations) of a SEVESO establishment and issuing of the Construction or Operation Permits. However, Maltese Authority demanded full evaluation of SRs and fulfillment of all requirements prior to issuing Permits for siting of the new LNG plant and for Operations.**

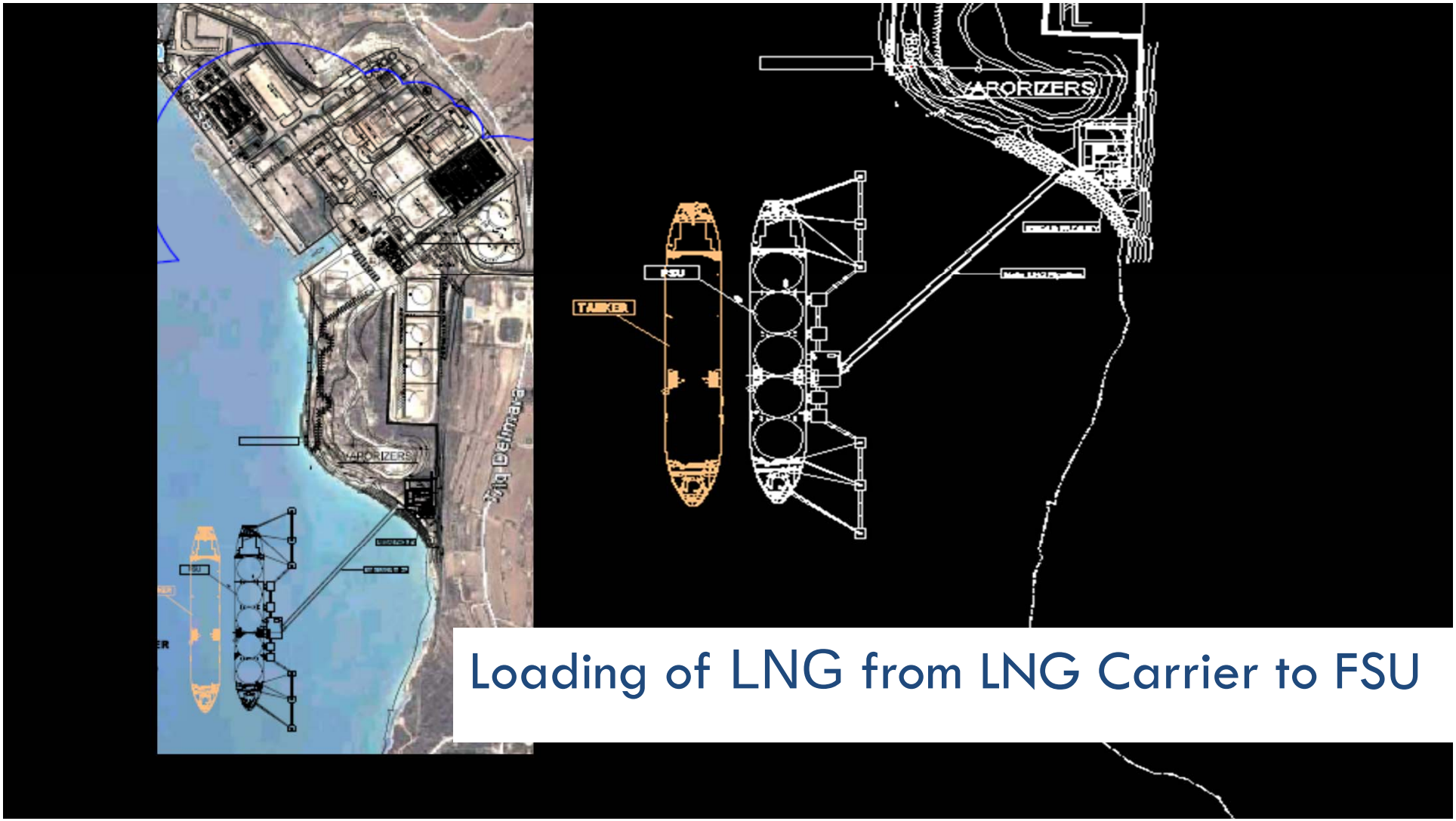
The new LNG Plant in Delimara Malta

Process & Storage Units

- **ELECTROGAS MALTA (EGM : LNG /NG)**
  - **FSU (Floating Storage Unit)**
  - **LNG / Boil Off Gas systems**
  - **RGU (Regasification Unit)**
  - **NATURAL GAS pipelines to CCGT GRS (D4 PP) & D3PP GRS**
- **ENEMALTA PS (ENE : HFO / Diesel)**

The general process

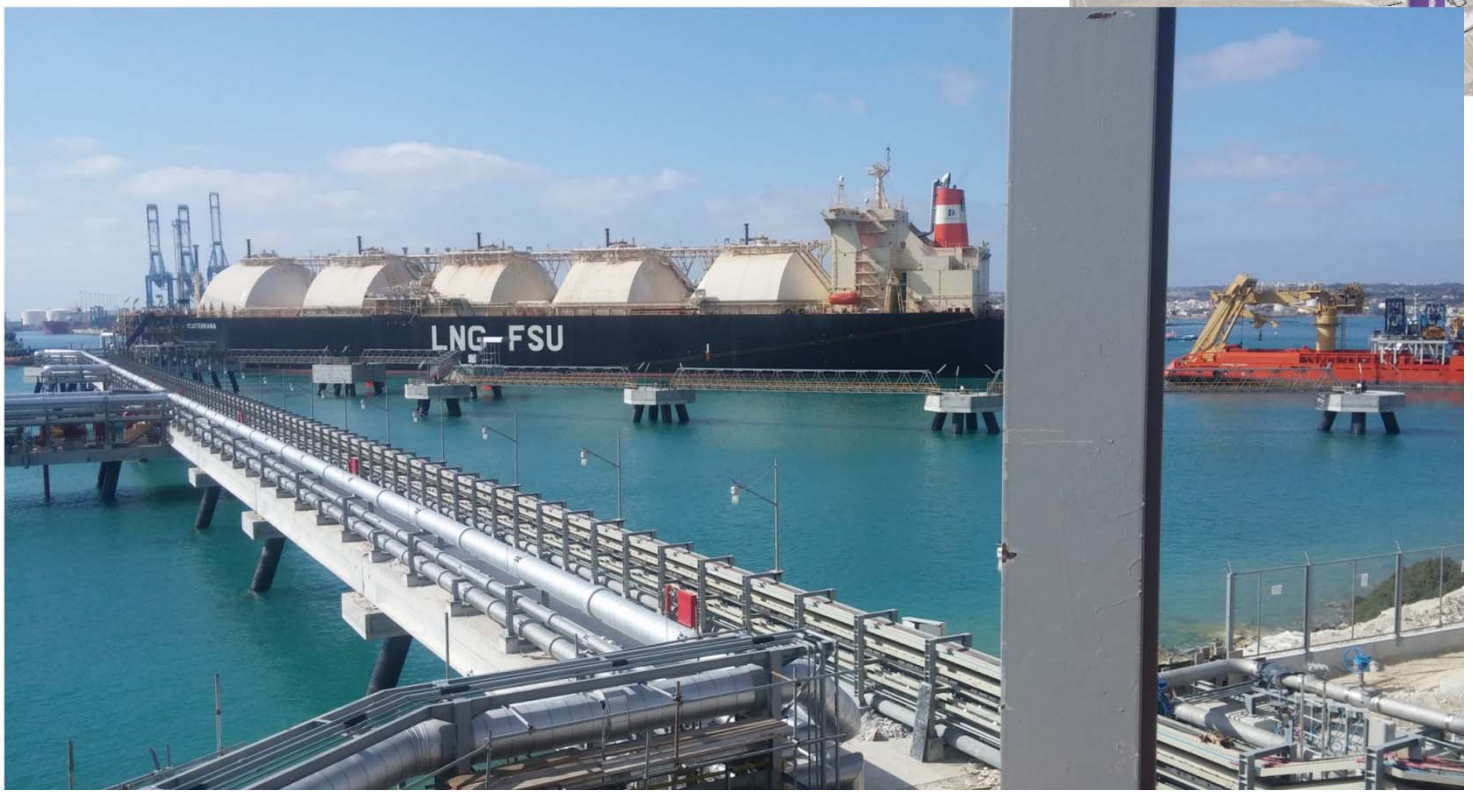




Loading of LNG from LNG Carrier to FSU

The new LNG establishment in Delimara Malta

- FSU (Floating Storage Unit)
- LNG / Boil Off Gas systems



The new LNG establishment in Delimara Malta

Jetty : LNG / Boil Off Gas Pipes

The new LNG establishment in Delimara Malta

Power Plant, HFO Carrier, Jetty, FSU

LNG site permits

Despite that QRA is NOT a legal requirement in Malta and that also NO direct link exists between Operation Permit of new establishments and SEVESO requirements within the regulatory framework in Malta (Law LN 179/2015),

Maltese Authorities (MEPA, OHSA) requested that

- Separate Safety Reports are developed from different Operators for individual units
  : the FSU, LNG / BOG systems, RGU, NG pipelines, and the D3 & D4 Power Plants
- all Safety Studies include quantification of Risk,
- all Seveso Reports (SRs, EPs, SMSs) are supplemented by a Coordinated Report for the entire establishment including an overall QRA study
- **all Seveso Reports (SRs, EPs, SMSs) and relevant Hazard and Risk studies are**
  - **completely evaluated according to the SEVESO requirements, and**
  - **fully approved by MALTA COMAH authorities prior to issuing both Construction and Operation permits.**

"SEVESO" REPORTS developed & evaluated for DELIMARA LNG Project (2014-2017)

- **Safety Reports (SRs** ver03 Sept. 2016**) : ENE SR and EGM SR** with supplementary reports and documentation **(Separate reviews for more than 100 documents /studies);**

  Descriptions of Environment, Establishment, Installations, Design, Process Operations, Dangerous Substances (flammables); Hazard Analysis, Major Accident Scenarios, Consequence Analysis, Domino Effects, Risk Assessment, Safety Measures.

- **Internal Emergency Response Plans (ERPs) : ENE IEP and EGM ERP (Separate reviews for FSU; Jetty; RGU; D4PP)** Limitation of Consequences & Mitigation

  Alert-Evacuation, Detection, Emergency Shut Down, Firefighting, Roles, Response, Drills.

- **Safety Management Systems (SMSs) with the Major Accident Prevention Policy (MAPP) : ENE SMS and EGM SMS (Separate reviews for FSU; RGU; D4PP)**
- **COORDINATED REPORTS : Coordinated SR, Coord. ERP and the Coord. SMS**

Final versions of "SEVESO" Reports (as published):
after construction of new installations and modification of the existing

- **AECOM SR ver. 03 (ELECTROGAS) : (new Units)**
  - Safety Report for **FSU (immobilized vessel)**, EPC1 (CCGT) and EPC2 (LNG Terminal)
  - Emergency Response Plan
  - SMS (including Major Accident Prevention Policy)
- **SGS SR rev. 03 (ENEMALTA) : POWER STATION (P/S) (existing and modified Units)**
  - ENE Safety Report
  - Emergency Response Plan
  - SMS (including Major Accident Prevention Policy)
- **SGS (ENEMALTA / ELECTROGAS / D3 PG) (existing, modified and new Units)**
  - Coordinated Safety Report for Delimara P/S, FSU and LNG Terminal

Evaluation of "SEVESO" REPORTS

A. **Compliance with SEVESO III regulatory requirements (obligations of operators)**

B. **Against Criteria of Hazard Analysis, Risk Assessment & Risk Acceptability**

C. **Overall, for Completeness, Correctness and Credibility of data through a SEVESO Evaluation CHECKLISTs of UNECE** (United Nations Economic Commission for Europe)

(A) Compliance with SEVESO III requirements

Maltese LN 179 of 2015 Occupational Health & Safety Act (CAP 424) "Control of Major Accident Hazards Regulations 2015" transposing SEVESO III Directive 2012/18/EU "on the control of major-accident hazards involving dangerous substances" repealing Dir. 96/82/EC.

Completeness and Adequacy of information and safety related documentation contained in SEVESO Safety Reports, are evaluated through:

EC Guidelines on:

- The preparation and assessment of Safety Report to meet the requirements of SEVESO Directive (art. 10 SEVESO III - reg. 8 of LN 179 /2015),
- SEVESO Inspections - checklists (art.20 SEVESO III - reg. 16 LN 179/2015),
- Emergency Plans (internal & external, art. 12 & Annex IV of SEVESO III)
- MAPP & Safety Management System (art. 10 & Annex III of SEVESO III)
- Evaluation of SMS and Emergency Plans (EC checklists and **Industrial practices**)

(B) Hazard Analysis & Risk Assessment

Completeness and Correctness of results contained in SEVESO Safety Reports, are evaluated through :

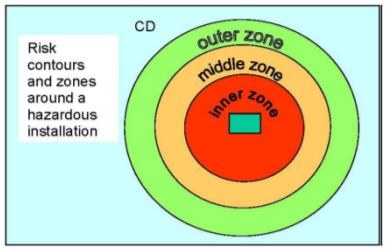
EU and International Guidelines and Practices (UK, France, Netherlands, Germany, Italy, Ireland, Belgium, Greece, Cyprus) **for**:

- Identification of major-accident Hazards (HAZOP/HAZID);
- Identification of major-accident Scenarios (Bow-Ties, FTA, ETA);
- Assessment of Scenarios' Consequences (Pool Fires, Flash Fires, Jet Fires, Explosions, RPT : Rapid Phase Transition, No BLEVEs);
- Measures, safeguards and procedures to minimize Hazards, to prevent major-accident Scenarios and to limit Consequences (follow up of above studies and of provisions in SMSs and Emergency Plans);
- Risk Assessment approaches and Risk Acceptability Criteria.

Risk Acceptability Criteria (references)

- Land Use Planning Policy, Environmental Planning in Malta, (New Version 2015, revised MEPA, Land Use Planning Policy 2004)
- Probabilistic accident assessment in the context of the French regulation, HAL Id: ineris-00973347 http://hal-ineris.ccsd.cnrs.fr/ineris-00973347
- HSE, Health and Safety Executive UK, 'PADHI – HSE's Land Use Planning Methodology', http://www.hse.gov.uk/landuseplanning/padhi.pdf
- Purple Book, "Guidelines for quantitative risk assessment", CPR-18E RIVM, 2005
- Yellow Book, "Methods for the calculation of physical effects", CPR-14E TNO, 1993.
- Green Book, "Methods for determination of possible damage", CPR-16E TNO, 1990.
- International Association of Oil & Gas Producers OGP Process Release Frequencies – Risk Assessment Data Directory, March 2010.

Malta **Land Use Planning Policy** : MEPA (LUP Policy 2004 – rev. 2015) in line with the widely accepted LUP practice proposed by HSE UK LUP Policy PADHI System (based on **LOCATION SPECIFIC INDIVIDUAL RISK Criteria**)

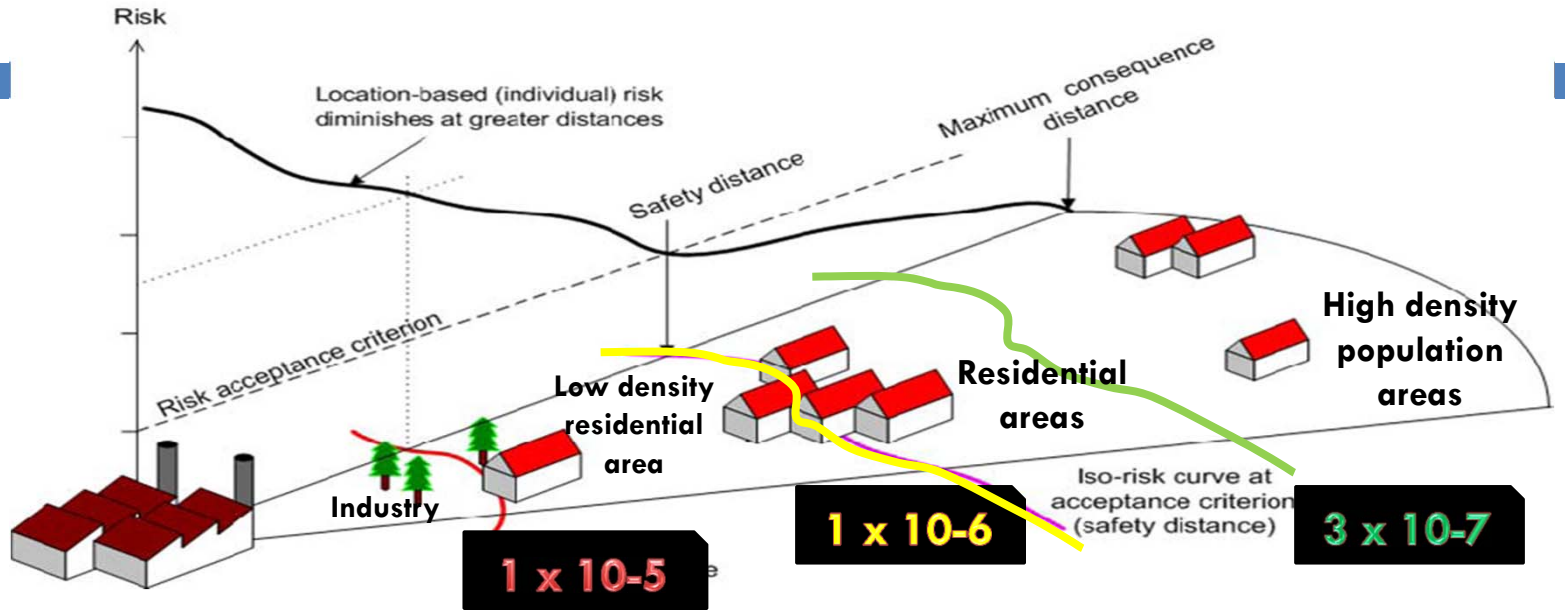


"Advise Against" (AA)

"Don't Advise Against" (DAA)

Location Risk of fatality (per year)	**1×10^{-5}**	**1×10^{-6}**	**3×10^{-7}**
Level of sensitivity of new Developments	**Developments in Inner Zone**	**Developments in Middle Zone**	**Developments in Outer Zone**
Level 1 e.g. Factories	DAA	DAA	DAA
Level 2 e.g. Houses	**AA**	DAA	DAA
Level 3 e.g. Vulnerable members of society (schools, old people's homes)	**AA**	**AA**	DAA
Level 4 e.g. Football ground/Large hospital	**AA**	**AA**	**AA**

Location Risk in the surroundings of COMAH sites



- **Safety Distance** or **Consultation Distance** indicates the point at which the **Risk falls below the Risk Acceptance Criteria** i.e. at greater distance the risk to individuals **is acceptable.**
- Iso-Risk Curves show the geographic distribution of location-specific individual risk (LSIR)
- Risk is **negligible** at any distance greater than Maximum Consequence Distance

(C) UNECE CHECKLISTs

Completeness, Correctness and Credibility of data contained in all "SEVESO" REPORTS (Safety Reports, Emergency Plans and Safety Management Systems, and Coordinated) are evaluated and presented through :

UNECE/UBA Checklists for the Evaluation of SEVESO Safety Reports

"UNECE convention on the transboundary effects of industrial accidents and EU SEVESO Directive by a consistent Checklist system"

Sectoral Checklists : SCLs 1 to 6

- Description of Environment & Site (**SCL-1**)
- Main activities and products for single installations (**SCL- 2**)
- Dangerous Substances (**SCL-3**)
- Hazard Identification, Risk Assessment and Preventative measures (**SCL-4**)
- Limitation of Consequences & Mitigation (**ERP assessment : SCL-5**)
- SMS (**MAPP & SMS assessment : SCL-6**)

Ten Procedural steps in evaluating the "SEVESO" REPORTS

(1/2)

1. Review of Descriptions & Data in the SRs: Environment, Installations (technical, design, process data & documentation);
2. Requirements for supplementary data;
3. Agreement with COMAH Authority (and EGM & ENE) on the safety/process design parameters, good industrial practices and standards used;
4. Agreement with COMAH Authority on the Risk Assessment approach, the Consequence Assessment criteria and Risk Acceptability criteria;
5. Review of Hazard Studies (deviations, safeguards, recommendations);

Ten Procedural steps in evaluating the "SEVESO" REPORTS

(2/2)

6. Review of Risk Analysis : the assumptions for Worst Case Scenarios (WCSs), software simulation parameters, consequence assessment, thermal radiation and overpressure effects, etc; Evaluation and Validation of the consequence assessment results and of scenarios frequencies;
7. Calculation of the Location Specific Individual Risk (LSIR) and Societal Risk FN Curve for the WCSs using the EFFECTS and RISKCURVES 9.0.26/TNO software packages;
8. Review of SMSs and Emergency Plans provisions & procedures; Requirements for supplementary data;
9. Completion of UNECE Evaluation Checklists, SCLs (1-6) for SRs, SMSs & ERPs;
10. Development of **COMAH Assessment Reports for SRs, SMSs and ERPs** with the results and recommendations (published).

Two Evaluation Phases : 1st at "Detailed Design"

- Design, Process & Operations : Ref. to Basic & Detailed Design
- Hazard Analysis HAZID/HAZOP (with reference to detailed design and **prior to construction**) – Recommendations
- Selection of WCs : from HAZOP/HAZID ; Calculation of Consequence and Frequencies of scenarios (WCSs + scenarios with CZs within establishment boundaries) : focus on WCSs and Domino
- Risk Assessment (Consequence based & Frequency of Scenarios) ; Risk Acceptability criteria (Risk Matrix as "Societal Risk" Criterion; IR Criteria agreed upon; LSIR and contours FN curve developed in COMAH Assessment report)
- Procedures/Provisions of SMS and Emergency Plans (internal ERP and inputs to external ERP) – linked to major accidents and hazards

Two Evaluation Phase : 2nd after Construction

"As Built" before Commissioning

- Modifications to Design, Process & Operations (compared to detailed design) related to major accident hazards : Ref. to construction plans
- Hazard Analysis : review of HAZOP / HAZID recommendations (Action Lists with reference to implemented safeguards)
- Additional Accident Scenarios and Re-evaluation of Consequence (follow up of the assessment of initial SRs versions)
- Reassessment of Risks (check whether within acceptable/tolerable limits)
- Additional Procedures/Provisions of SMS and Emerg. Plans (internal and inputs to external EP) related to major accidents (follow up of assessment)
- **RESULTS and CONCLUSIONS of Evaluation of "SEVESO" REPORTS** (before commissioning), and
- **Recommendations to Authority for SEVESO INSPECTIONS** (during/after commissioning).

Results of Safety Report Evaluation

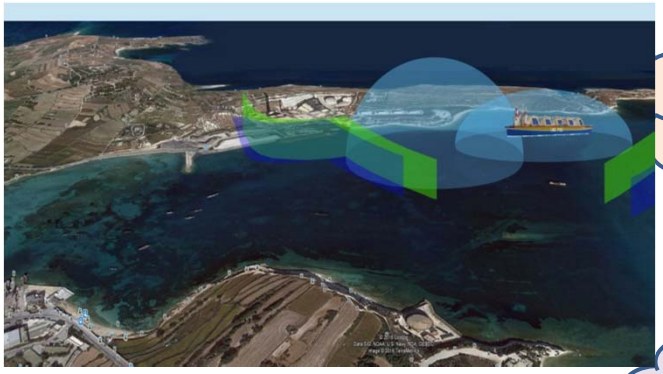
- UNECE Checklists (overall)
- Risk Assessment

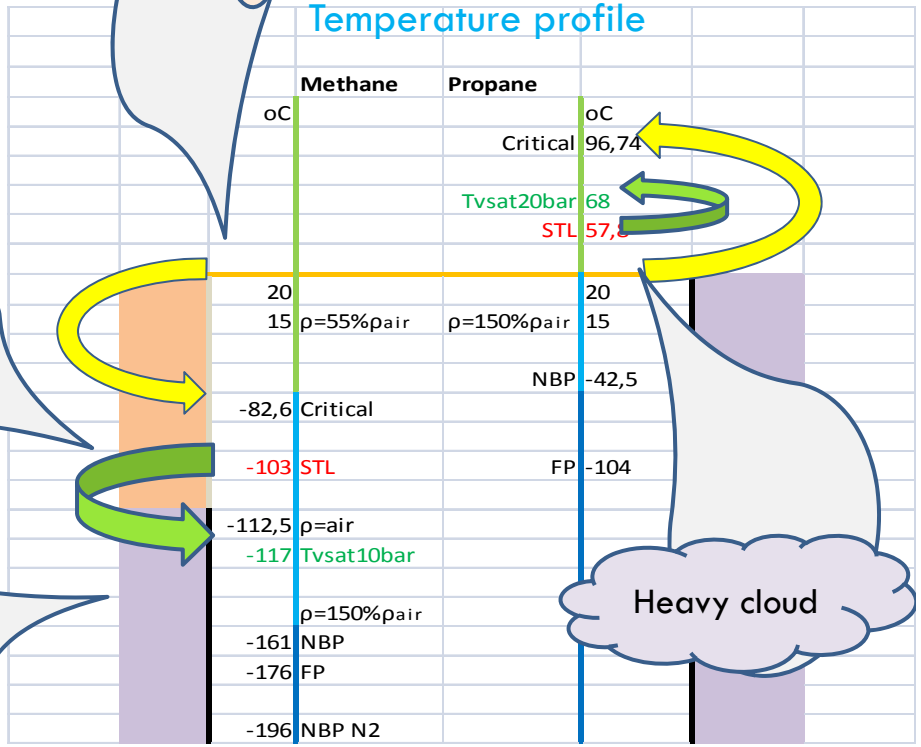
Dangerous Substances

LNG is different than LPG

the range of LNG compositions to be received by the FSU:

Component (%mol)	Methane	Ethane	Propane	Butane	Nitrogen
Lean LNG	93.28	6.14	0.17	0.03	0.38
Rich LNG	87.53	8.34	2.18	0.78	1.17





NO BLEVE when Liquid **Tvsat** below **STL:**

Superheat Temperature Limit (Reid 1979) STL = 0.895 x Tcrit (oK)

Evaluation Results : UNECE Checklists

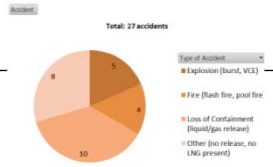
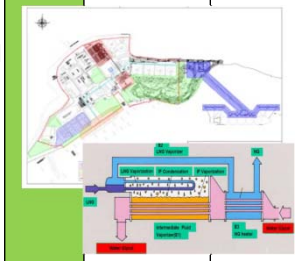
The UNECE Checklists (SCLs 1-6) have been completed separately for SRs, ERPs & SMSs of EGM and ENE and for the Coordinated Reports (**total 93 articles**)

- Description of Environment & Site (**SCL-1) : 14 articles**
- Main activities and products for single installations (**SCL- 2) : 8 articles**
- Dangerous Substances (**SCL-3) : *7* articles**
- Hazard Identification, Risk Assessment and Preventative measures (**SCL-4) : 18 articles**
- Limitation of Consequences & Mitigation (**ERP assessment : SCL-5**) : **9 articles** (**50 topics**)
- SMS (**MAPP & SMS assessment : SCL-6) : 37 articles**

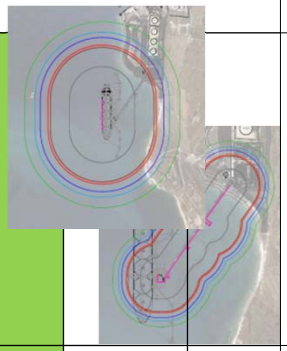
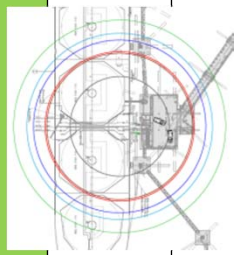
The Contents of "SEVESO" REPORTS appeared to be Complete, Correct and Credible.

The final Results of the Evaluation are presented in the **COMAH ASSESSMENT REPORTS (published)** in the format of **Specific Recommendations** before Commissioning and **General Recommendations** after Commissioning.

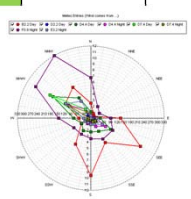
UNECE Checklists : Completeness (SCL -4 example)

			Yes Limited No	Evaluation Comments (examples)
COMPLETE				
4.1	Is the adopted approach for the applied risk analysis described and does it correspond to the national requirements, if defined? 	• **Definition of the different categories of frequency** • **Reference to data bases and/or generic data** • **Models for calculation and representation of the consequences** • **Values (end points) for accidental loads (explosion loads, heat radiation, toxicity, etc.)**		Data bases verified **Actual ignition sources considered in the revised ignition probabilities** Common Risk Matrix agreed upon **Malta LUP Policy criteria** End Point Values for Consequences agreed upon Verified Domino criteria
4.2	Does the risk analysis (RA) cover the entire facility?	• **The entire site** or on a specific part of the plant, or on hazards associated with a certain operations • **Risks to human beings, assets and the environment** • Considering external impacts (landslide, flooding, earthquake) • **Which area/activity is the most hazardous and how is this considered**		Assumptions / **Risk Criteria** as verified are considered in the revised SR **for all sites** Revised SR includes FBRs, LNG recirculation, etc. NG pipe effects in the revised SR; **Domino Zones** included (risks to assets) **Environmental risks considered (HFO/DO)** Domino from NG pipe in SR and coordinated SR Risk priority areas / equipment considered

UNECE Checklists : Correctness (SCL -4 example)

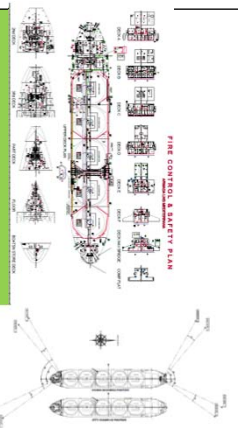
			Yes	Limited	No	Evaluation Comments (examples)
CORRECT						
4.12	Do the assumptions inside of the described scenarios fit the reality?	Parameter of scenarios compare with equipment data like flow/pressure				Assumptions assessed / verified Catastrophic & partial ruptures of equipment examined Release rates verified Release from pipes FBR considers back flows Extent of largest LNG pools verified (on water, in RGU) **LNG evaporation rates defined / verified**
4.13	Is the calculation of the scenario dimensions done by approved models?	Models described within national/international regulations or literature				PHAST / DNV & EFFECTS / TNO Software packages verified for LNG and other dangerous substances Consequence Models approved

UNECE Checklists : Credibility (SCL -4 example)

			Yes	Limited	No	Evaluation Comments (examples)
CREDIBLE						
4.17	Is the used applied risk analysis consistent?	Approached method is used for all identified critical installations				Verification of Assumptions and sources Consistent implementation of approach for site installations and safety critical equipment Risk Analysis approaches appropriate for major-accident hazards
4.18	Are the accident parameters given to calculate the scenarios by another party?	Wind speed, released mass, diameter of burning pool, mass within a cloud of explosive material				Weather Stability classes & wind speed verified (Meteo data) Data and used parameters provided for all scenarios; Output and "intermediate" data; Analytical soft files provided Release rates limitations verified; LNG pools and evaporation rates verified Time of NG cloud dispersion defined **Confinement of NG cloud examined (verified against topography)**

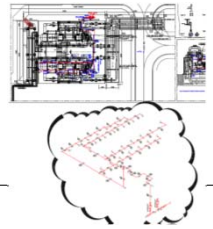
UNECE Checklists : Completeness (SCL -5 example)

			Yes	Limited	No	Evaluation Comments (examples)
COMPLETE						
5.1	Is the description of the equipment in the plant to limit the consequences of major accidents provided?	• Devices for limiting the size of accidental releases (scrubbing systems, water spray or water curtain, emergency flare systems, etc.) • Vapour screens, emergency catchpots or collection vessels, emergency shut-off valves • Automatic shut down systems • Emergency venting including explosion panels • Inerting systems • Equipment for removal of contaminated soil and other material • Booms and skimmers for spillages to water • Temporary storage arrangements e.g. portable storage tanks, for the contaminated material				Provided in SRs, ERPs For FSU/ RGU / NG pipes : ESDs, TRVs, PSVs, PRVs, RGU impounding basin, NVCC flare, PERC, Firefighting, Water Spray system, etc. N2 inerting system in FSU FSU storm mooring location (nautical study) Measures to isolate air intakes from NG cloud in RGU Control Room description; Electrical Building arrangement Supplementary data provided
5.4	Is the external equipment to limit the consequences of major accidents described?	Equipment of external firefighters				External Emergency Plan developed



Seriousness of event	Level of emergency activation	
MODERATE EVENT	E3	*Potential emergency situation*
SERIOUS EVENT	E2	*Limited emergency*
VERY SERIOUS EVENT	E1	*Full emergency*

UNECE Checklists : Correctness / Credibility (SCL -5 example)

			Yes	Limited	No	Evaluation Comments (examples)
CORRECT						
5.6	Does the equipment of emergency response crews compare with potential hazards?	• Firefighting foam if needed • Water shields against dispersion of gas clouds or heat radiation • Flow rate and availability of water for firefighting				Data in ERPs and SRs 
CREDIBLE						
5.7	Has the identification of installations, which need protection or rescue intervention been done?	• Cooling of installations against heat radiation • Plans for evacuation of buildings				Data in ERPs and SRs 

Evaluation Results : Risk Assessment

Three different Criteria for Risk Assessment

1. Risk Assessment Matrix
2. Location Specific Individual Risk (LSIR)
3. Societal Risk (FN curve)

Criterion 1. Risk Assessment Matrix :

According to the French Approach on Evaluation of Risk Control as based on the potential consequences and predicted frequency **for each** accident scenario

Addresses Risks to individuals or groups of people among the public

		Seriousness/Severity of Scenario Consequences				
Probability of Scenario	**per year**	**1 Moderate**	**2 Serious/ Medium**	**3 Major/ Significant**	**4 Catastrophic**	**5 Disastrous/ Extreme**
A Likely	Greater than or equal to 10^{-2}					
B Unlikely	Greater than or equal to 10^{-3} and less than 10^{-2}				Unacceptable	
C Very Unlikely	Greater than or equal to 10^{-4} and less than 10^{-3}					
D Extremely Unlikely	Greater than or equal to 10^{-5} and less than 10^{-4}	Acceptable		Tolerable if ALARP		
E Remote	Less than 10^{-5}					(*Yellow for Existing Plant* - Red for New Establishments

Severity of Consequences	Significant Lethal Effect	First Lethal Effect	Irreversible Effect
Extreme	PE>10	PE>100	PE>1000
Catastrophic	1<PE≤10	10<PE≤100	100<PE≤1000
Significant	PE≤1	1<PE≤10	10<PE≤100
Medium	0	PE≤1	1<PE≤10
Moderate	No lethal effects outside the facility		PE≤1
Note: PE=Persons Exposed			

Severity of Consequences :
End Point Values for Consequence Zones of scenarios (conservative)
Malta Land Use Planning Policy (MEPA LUP Policy 2004 / rev. 2015)

Effects		Significant Lethal Effects	First Lethal Effects	Irreversible Effects (No fatality)
	Hazard Zones: Threshold / End point values			
	Domino Zone **99% fatality**	**Inner Zone** **Very Serious Hazard** **50% fatality**	**Middle Zone** **Serious Hazard** **1% fatality**	**Outer Zone** **Significant Hazard** **No fatality**
Thermal Radiation Thermal Dose	**37.5 kW/m²**	**15 kW/m²** **1800** (*to 2000*) **TDU**	**5 kW/m²** **500** (*to 1000*) **TDU** for short duration effects	**3 KW/m²**
Overpressure	**700 mbar**	**300** (*to 350*) **mbar**	**140 mbar**	40-50 mbar
Toxic	-	**LC50: Lethal concentration for 50% lethality**	**LC1: Lethal concentration for 1% lethality**	IDLH

[1] TDU: Thermal Dose Units in $((kW/m^2)^{4/3})sec$

Evaluation Results : Risk Assessment Matrix before ALARP study

		Seriousness/Severity of Scenario Consequences				
Probability of Scenario	**per year**	**1 Moderate**	**2 Serious/ Medium**	**3 Major/ Significant**	**4 Catastrophic**	**5 Disastrous/ Extreme**
A Likely	Greater than or equal to 10^{-2}					
B Unlikely	Greater than or equal to 10^{-3} and less than 10^{-2}	37	5			
C Very Unlikely	Greater than or equal to 10^{-4} and less than 10^{-3}	65	22	28		
D Extremely Unlikely	Greater than or equal to 10^{-5} and less than 10^{-4}	49	51	32	7	
E Remote	Less than 10^{-5}	29	35	8	2	7

Unacceptable

Acceptable

Tolerable if ALARP

Evaluation Results : Risk Assessment Matrix after ALARP study (further safeguards defined)

		Seriousness/Severity of Scenario Consequences				
Probability of Scenario	**per year**	**1 Moderate**	**2 Serious/ Medium**	**3 Major/ Significant**	**4 Catastrophic**	**5 Disastrous/ Extreme**
A Likely	Greater than or equal to 10^{-2}					
B Unlikely	Greater than or equal to 10^{-3} and less than 10^{-2}	37	5			
C Very Unlikely	Greater than or equal to 10^{-4} and less than 10^{-3}	65	27	16		
D Extremely Unlikely	Greater than or equal to 10^{-5} and less than 10^{-4}	49	51	44	1	
E Remote	Less than 10^{-5}	29	35	8	8	7
	Less than 10^{-6}					7

12

6

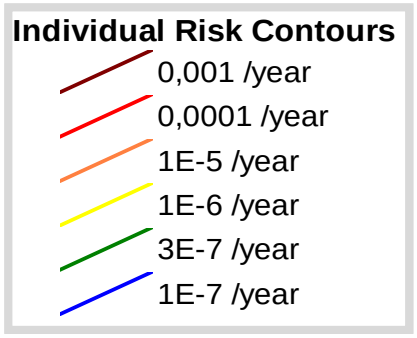
Acceptable

Tolerable if ALARP

Criterion 2. Location Specific Individual Risk (LSIR):

According to Malta Land Use Planning Policy (MEPA LUP Policy 2004 / rev. 2015)

Location Risk of fatality (per year) for an individual among the public at any location	Higher than 1×10^{-5}	1×10^{-6}	Less than 3×10^{-7}
	Unacceptable	Broadly Acceptable	Acceptable

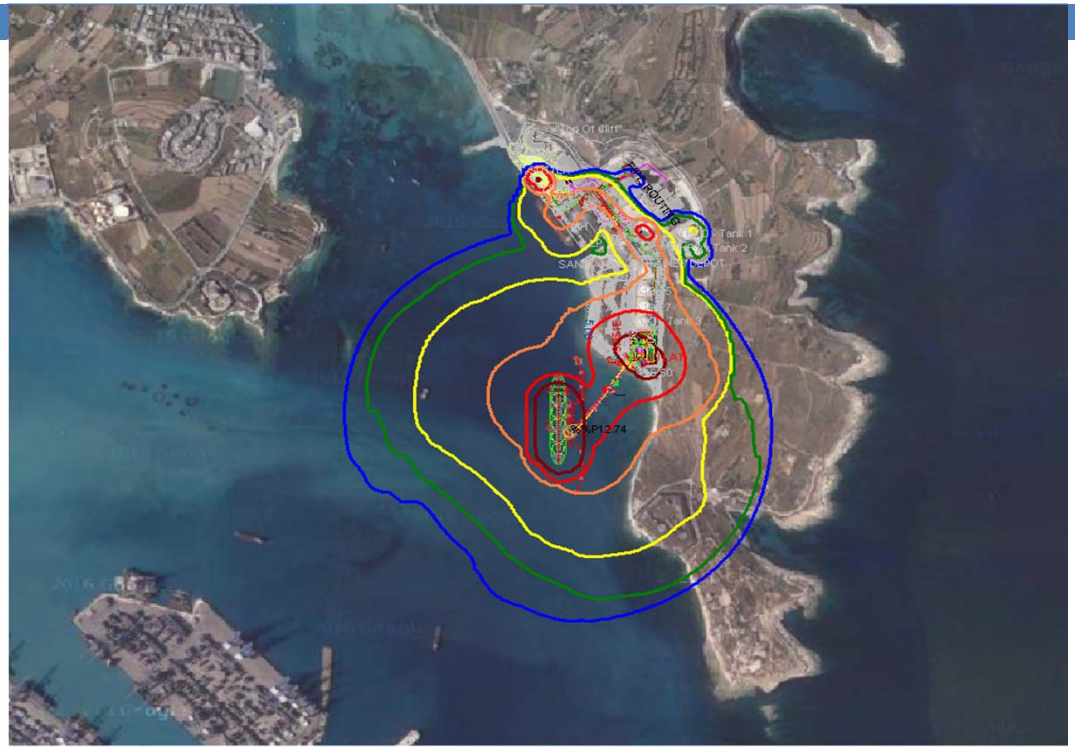


LSIR is the Risk of fatality for an individual with 24/7 presence at any location for ALL accident scenarios

Evaluation Results : Location Specific Individual Risk (LSIR)

LSIR based on outputs of SAFETY REPORTs (*EGM & ENE ver03, after construction)*

for 355 Accident Scenarios in total (LSIR contours on LAY OUT)



Risk of fatality of an individual

- 1 in 100,000 years
- 1 in 1 million years
- 3 in 10 million years

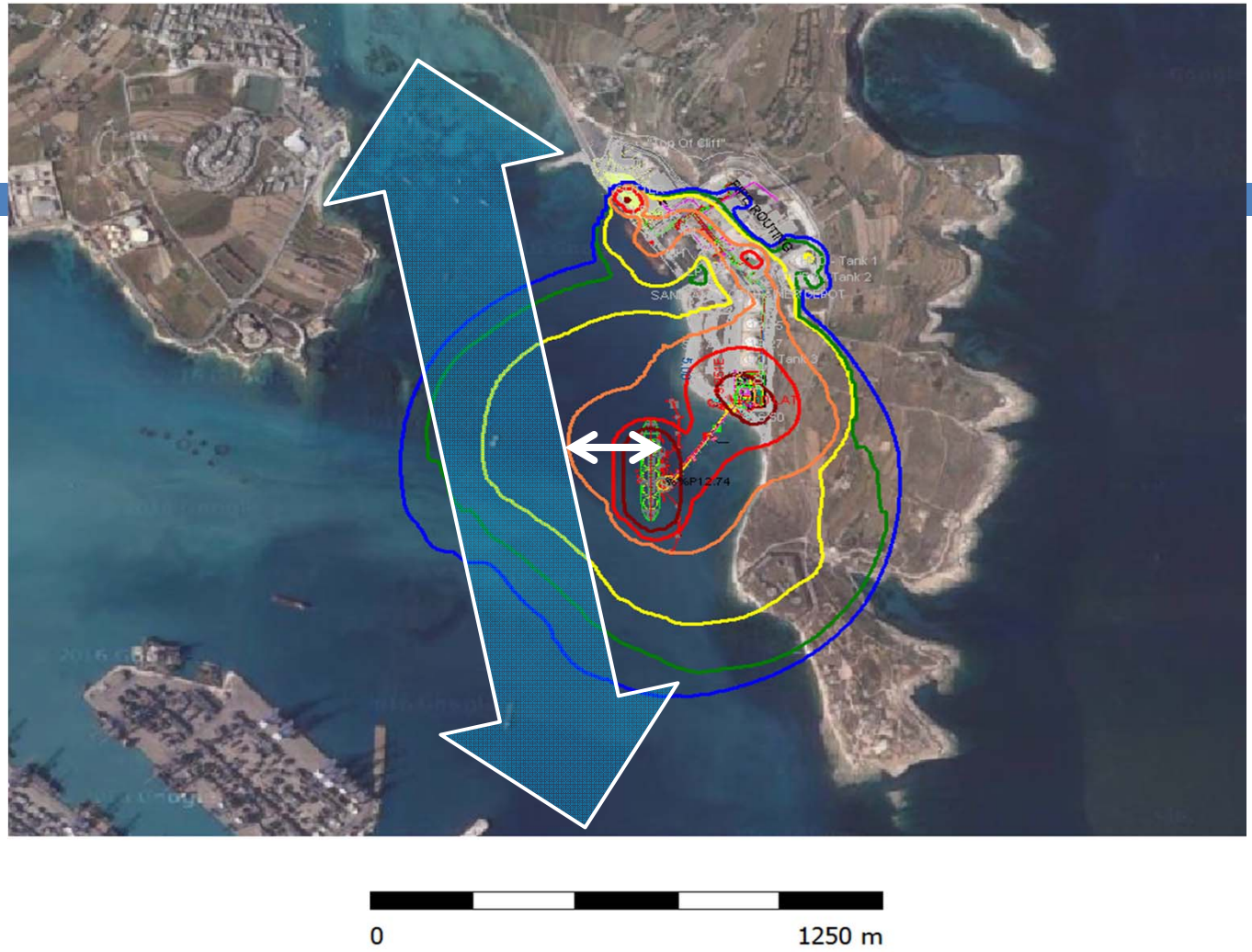
Individual Risk Contours

- 0,001 /year
- 0,0001 /year
- 1E-5 /year
- 1E-6 /year
- 3E-7 /year
- 1E-7 /year

0 1250 m

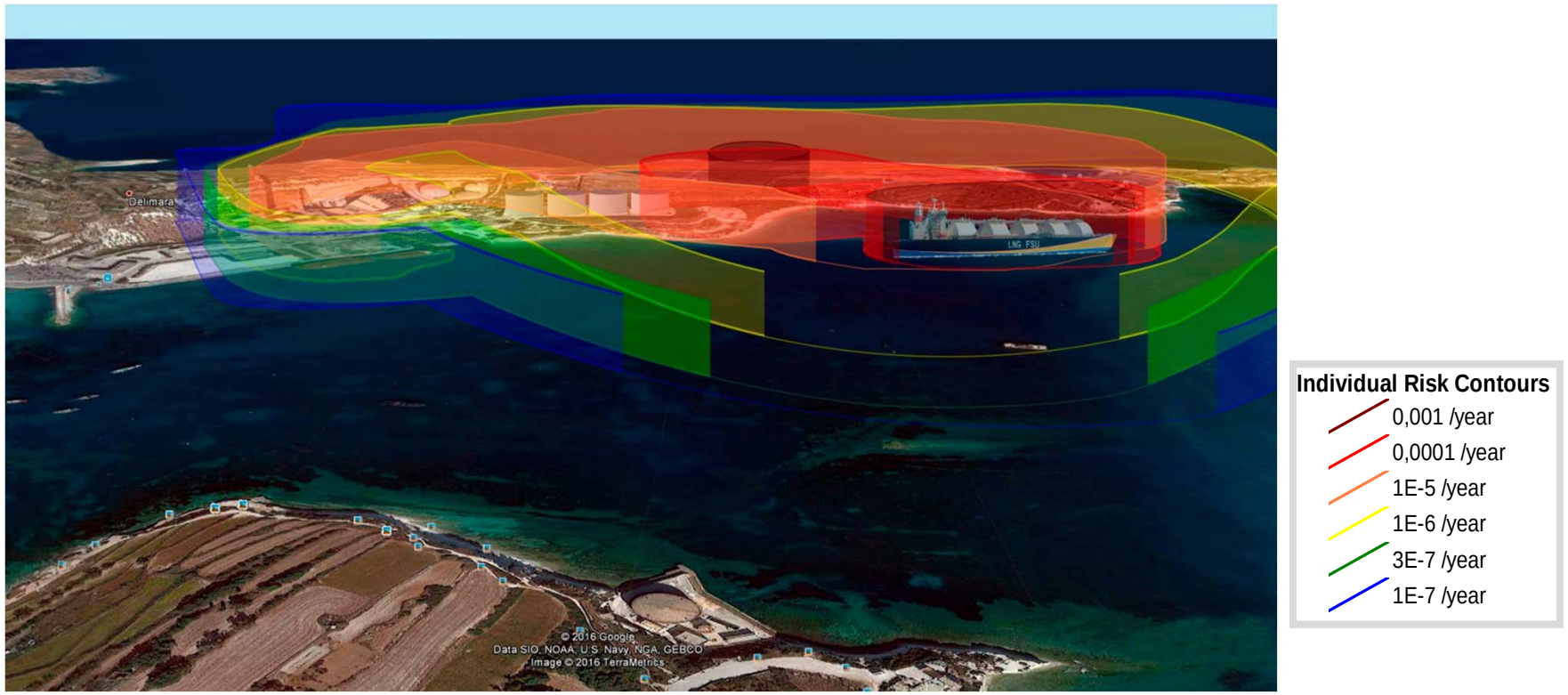
Exclusion Zones based on LSIR

Exclusion Zones : max 250m from FSU berth location are indicated by 10^{-5} risk contour (amber risk curve)



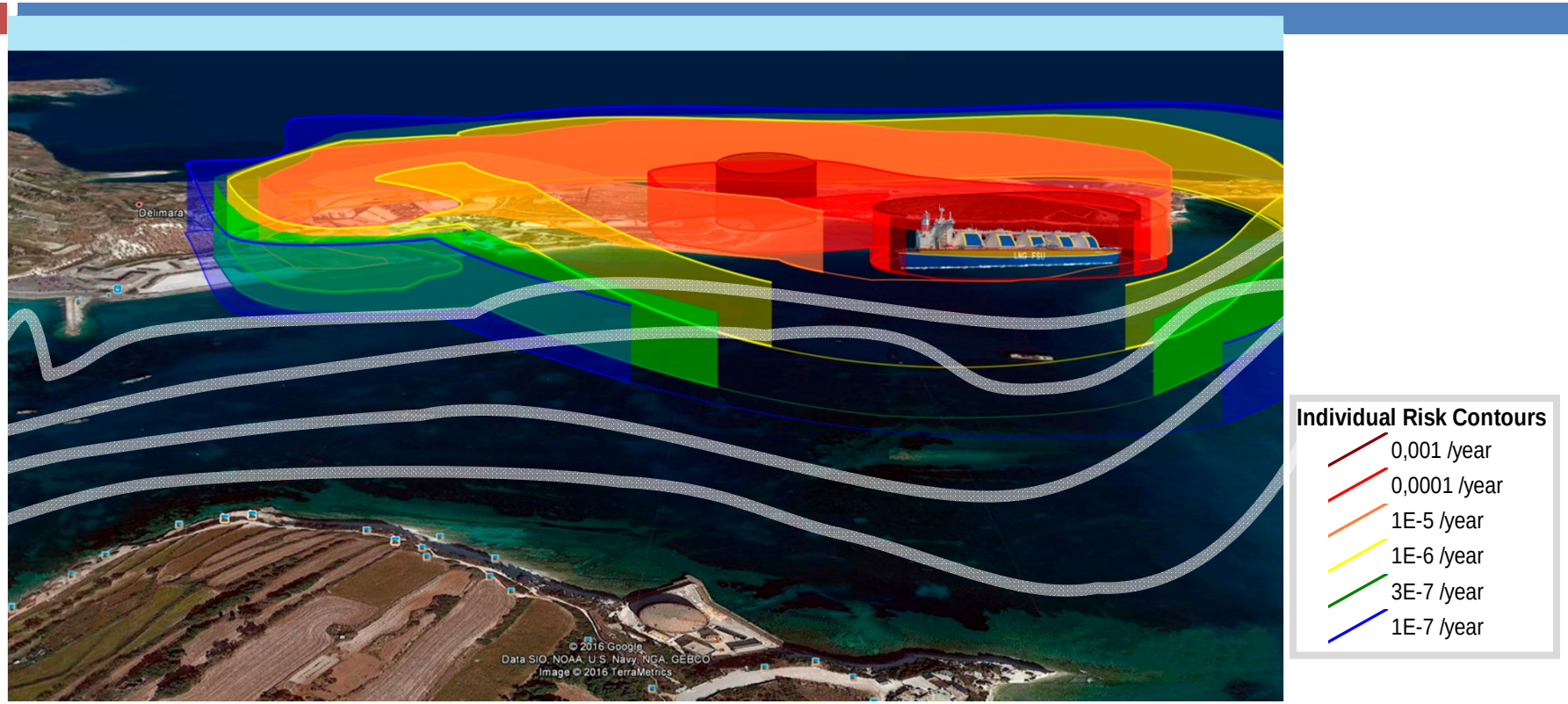
Evaluation Results : LSIR contours in 3D (*Bird's eye view*)

(355 Accident Scenarios in total)

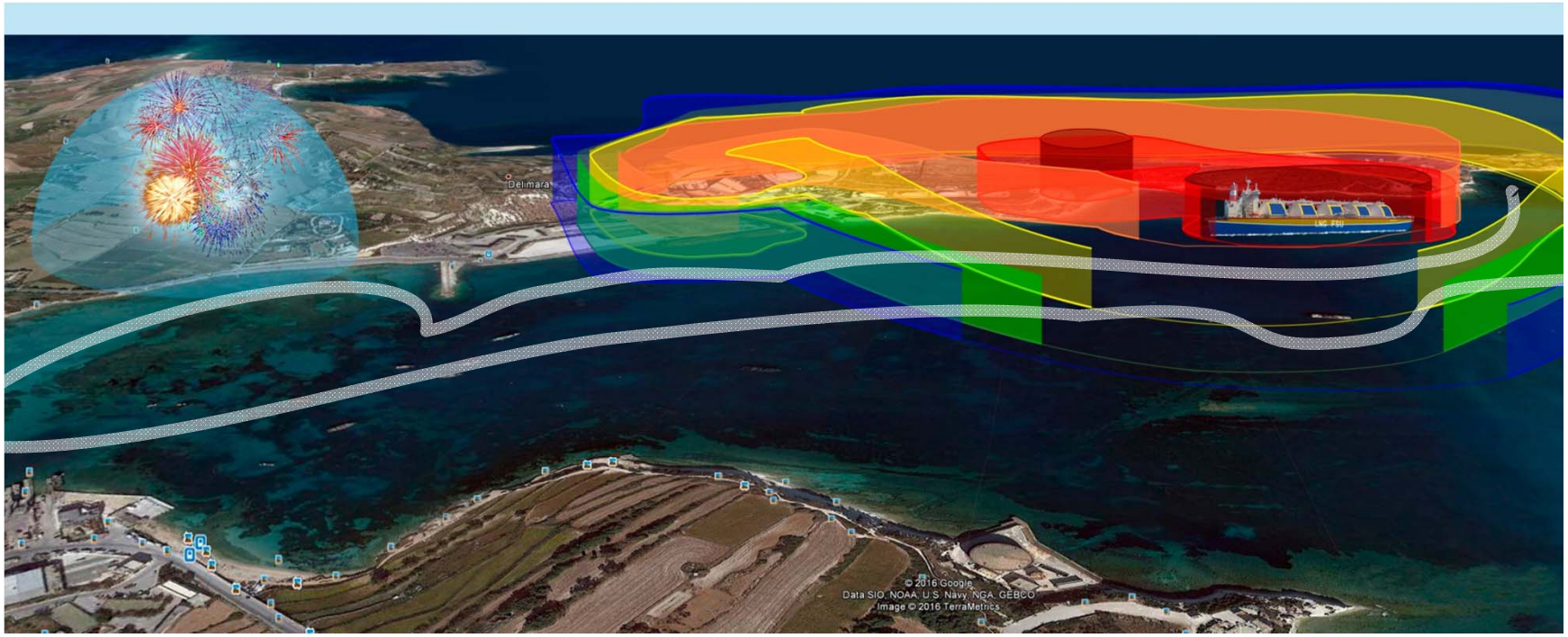


Evaluation Results : LSIR contours *(Bird's eye view)*

Examples of sailing routes without safety zones restrictions



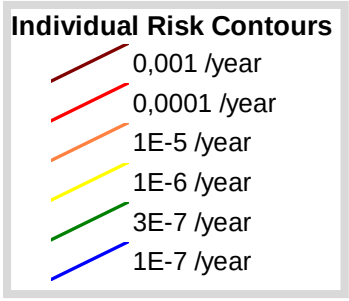
Risk level at all new and existing facilities in Delimara area is compatible with the surrounding activities (e.g. fire works)



Evaluation Results : Location Specific Individual Risk (LSIR)

for 355 Accident Scenarios in total

LSIR contours on LAY OUT : Zoom in to FSU and RGU area



Evaluation Results : Location Specific Individual Risk (LSIR)

for 355 Accident Scenarios in total

LSIR contours on LAY OUT : Zoom in to RGU area

r

0 125 m

Individual Risk Contours

- 0,001 /year
- 0,0001 /year
- 1E-5 /year
- 1E-6 /year
- 3E-7 /year
- 1E-7 /year

Evaluation Results : Location Specific Individual Risk (LSIR)

for 355 Accident Scenarios in total

LSIR contours on LAY OUT : Zoom in to ENE P/S, D4PP and D3 area

0 250 m

Individual Risk Contours

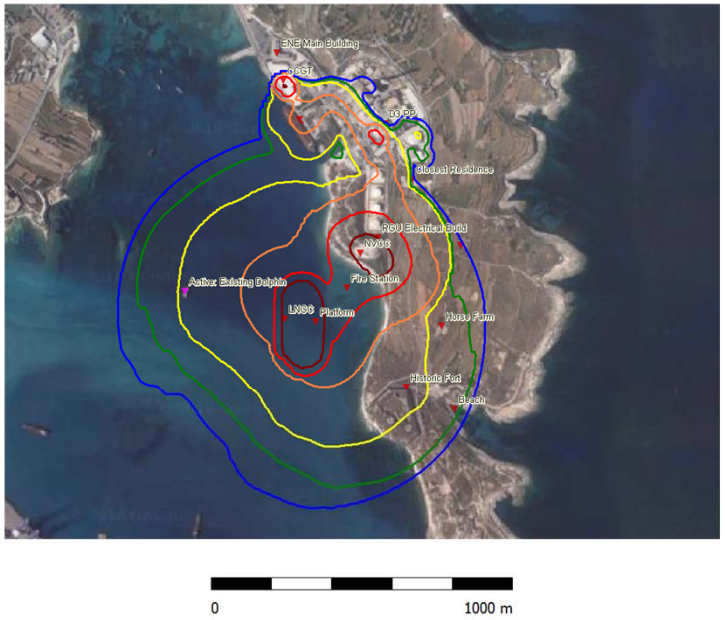
- 0,001 /year
- 0,0001 /year
- 1E-5 /year
- 1E-6 /year
- 3E-7 /year
- 1E-7 /year

Individual Risk at Locations of Analysis Points

for 355 Accident Scenarios in total

List of Analysis Points:

1. Agricultural Land
2. Beach
3. CCGT
4. Closest Residence
5. D3 PP
6. ENE Main Building
7. ENE Unloading Berth
8. Existing Dolphin
9. Fire Station
10. Historic Fort
11. Horse farm
12. LNG Carrier
13. NVCC
14. Platform
15. RGU Electrical Building



Individual Risk Contours

- 0,001 /year
- 0,0001 /year
- 1E-5 /year
- 1E-6 /year
- 3E-7 /year
- 1E-7 /year

Evaluation Results : Individual Risk for the public at Locations of Analysis Points

Acceptable

Broadly Acceptable

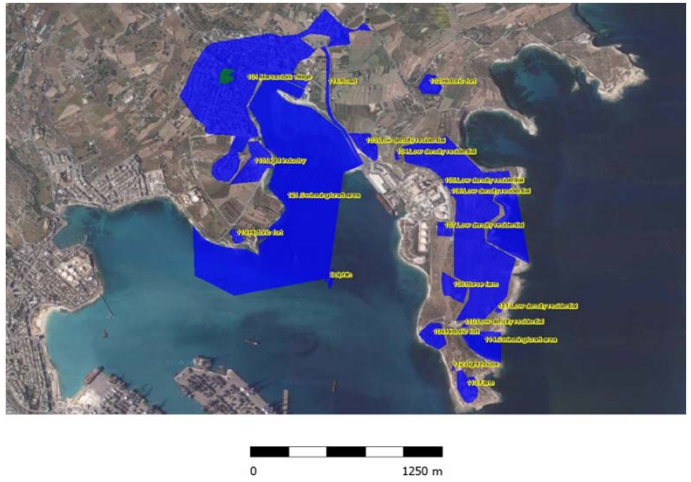
Unacceptable

Analysis Points	Location of Area in relation to the establishment boundaries	Total IR [/year]
ENE Main Building (6)	Inside (close to boundaries)	<1.00E-20
Agricultural land (1)	Outside	1.43E-07
Closest Residence (4)	Outside (close to boundaries)	1.80E-07
D3 PP (5)	Inside	3.34E-07
Beach (2)	Outside	4.35E-07
Horse Farm (11)	Outside	5.43E-07
Existing Dolphin (8)	Outside	1.38E-06
Historic Fort (10)	Outside	1.88E-06
ENE Unloading berth (7)	Within safety zone (close to boundaries)	7.09E-05
CCGT (3)	Inside	3.26E-04
Fire Station (9)	Inside (on Jetty)	3.29E-04
RGU Electric Building (15)	Inside	9.36E-04
NVCC (13)	Inside	2.67E-03
LNG Carrier (12)	Within safety zone (close to boundaries)	4.98E-03
Jetty Platform (14)	Inside	1.81E-02

Conclusions on Individual Risks to the public

- The level of overall Individual Risk (IR) is "acceptable" or "broadly acceptable" in all areas examined (Analysis Points) outside or in the close vicinity to the boundaries of the establishment where public is expected to be present, e.g. *in the areas of the neighboring agricultural land west to the establishment, the closest Residence east of the HFO tanks, the Beach and the Horse Farm to the south of the establishment.*
- The areas in which Individual Risk (IR) is found higher, are limited within the boundaries of the establishment where public is not present, e.g. *the areas of: ENE Unloading berth, the CCGT , the Fire Station on Jetty, the RGU Electrical Building, the NVCC , the FSU area including the area of LNGC and the Jetty Platform.*
- The locations of the ENE Main Building and D3 Power Plant within the establishment are areas of negligible individual risk for employees.

Criterion 3. Societal Risk (FN curve): According to Dutch Approach (most conservative)



Dutch Criterion ($F < F_{cr}$)

$F_{cr} = 10^{-5}$ for N = 10 people

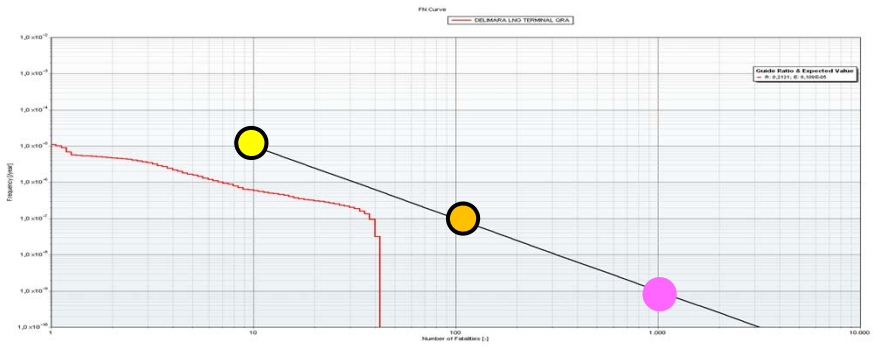
$F_{cr} = 10^{-7}$ for N = 100 people

$F_{cr} = 10^{-9}$ for N = 1000 people

F-N curve : Conditional Cumulative Frequency (F per year) of a number of expected fatalities (N) among actual population in the area around the establishment

vs.

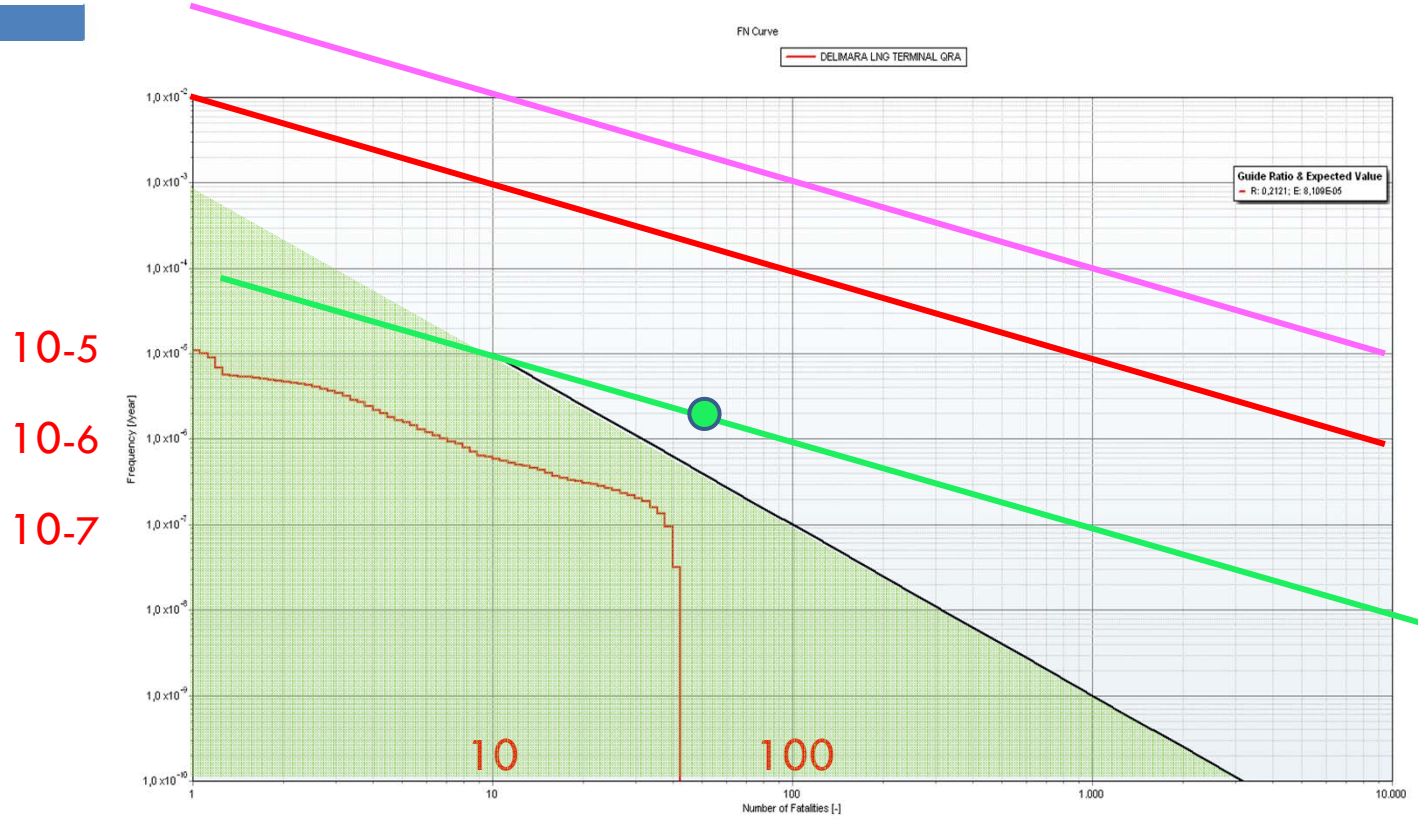
The guide value used in the Netherlands : $F=10^{-3}/N^2$



Evaluation Results : Societal Risk (FN curve)

Societal Risk based on outputs of SAFETY REPORTs (*EGM & ENE ver03*)

for 355 Accident Scenarios in total (FN curve vs. Dutch societal risk criterion)



10-5

10-6

10-7

Unacceptable employees

Unacceptable public

Acceptable public HSE

Conclusion on Risks to the public according to 3 different Risk Assessment Criteria

- The Risk Assessment Matrix
- The Individual Risk criterion (LSIR)
- The Societal Risk criterion (FN)

The COMAH Assessment Report concludes that :

The level of Risk posed by the new and existing facilities in Delimara Power Station

- **is within acceptable limits, and**
- **is compatible with the surrounding activities,**

provided that all safeguards considered or recommended in the COMAH Assessment of "SEVESO" Reports are properly implemented and maintained.

General remarks and points of interest for LNG plants with Floating Units (SRs, Risk Assessment, Inspections) 1/3

For the SR evaluation (completeness and adequacy); necessary also for SR development

- **Check Lists** with assessment criteria for SR contents, Internal Emergency Plans and SMS: if NO national guide exists a common list should be adopted (**large data volume**).
- Agreement on **end-point values** for Consequence Zoning and criteria for **Domino** Effects.
- **QRA** (Quantitative Risk Assessment) studies are essential.
- Authority to adopt **Risk Acceptance criteria** (**variety)** : LSIR (individual risk), Risk Matrix and FN (societal risk); conservative vs. non-conservative approaches used in EU & industry.
- Fixed number of **Worst Case Scenarios** (major accidents) from **systematic Hazard Analyses** of the specific process equipment and **final design** (delays from modifications).
- **Coordinated reports** are useful for QRA, Domino, Emergency Plans and SMS, in cases of many operators are involved in a single SEVESO establishment (different for Floating Units, for onshore units, P/Ss and NG pipeline).

General remarks and points of interest for LNG plants with Floating Units (SRs, Risk Assessment, Inspections) 2/3

For the major accident Scenarios in LNG establishments, Hazard Effects are sensitive to :

- Exact type of process equipment, inventories, operating conditions; **Hoses vs. Arms**, No LNG BLEVE at pressure lower than 10 barg, etc. **Good knowledge of the process.**
- LNG particularities e.g. **BOG management**, LNG Rollover in floating tanks (SIGGTO), FSRU PRVs (sized 100 times the normal BOR for Rollover; BS EN 1473:2007), etc.
- **Large breaches** in equipment (the largest, 1000mm, in the tanks due to ship collision or overpressure, FBR of LNG pipes, etc.) and **high release rates** produce WCSs.
- **The maximum LNG pool** (on water) determines the maximum effect zones and iso-risk contours around FSRU/FSU; Larger LNG evaporation rates produce shorter LNG pools.
- The maximum methane cloud (dispersion) appears on stable weather (class F) and low wind speed (2 m/s); depends on presence of local ignition sources in land uses.
- **Time for LNG release isolation** via ESD systems, PERC, gas detection, etc.

General remarks and points of interest for LNG plants with Floating Units (SRs, Risk Assessment, Inspections) 3/3

Risk level (QRA results) **depends on :**

- Vessel collision and LNG tank rupture probability.
- Frequency of LNG Loading/ Unloading; Use of Hoses instead of Loading/Unloading Arms; LNG pipelines on FSU and jetty; High pressure LNG lines;
- Failure rates of equipment; generally low rates (high standards, new constructions, etc).
- Ignition probabilities in the area (of FSRU or separately of FSU and RGU).
- Immediate vs. delayed ignition e.g. immediate ignition of large LNG pools on sea surface created by vessel collision, immediate ignition of cloud crossing the flare, etc.
- Accurate local meteo data; common vs. predominant weather stability classes, wind speeds and direction e.g. (F1, D4 vs. F2, D5).
- Availability and Reliability of safeguards, ESDs, SMS procedures, emergency plans, etc.

Thank you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Dr. George Papadakis