## Session F-2:PSA Applications I

**Paper #115**

# Applications of Quantitative Risk Assessment Technique on Liquefied Natural Gas Tanks System

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# Outline

Ⅰ 、Introduction

Ⅱ 、Methodology

Ⅲ 、Assessment Process

Ⅳ 、Conclusions

# I、Introduction (1 of 2)

- According to the Taiwan's Council of Labor Affairs (TCLA) Act 132 entitled, "Safety Inspection Rules for Dangerous Machines and Equipments", the Liquefied Natural Gas (LNG) tank is a specific facility and an internal inspection should be implemented by the end of a 15 year period.
- Due to the impact on supply of natural gas, the Institute of Nuclear Energy Research (INER) introduces the PRA technology to official of TCLA as an alternative to the required internal surveillance inspection.
- INER provides the Quantitative Risk Assessment (QRA) technical service to evaluate the potential risk and quantitative safety for the three first-phase Liquefied Natural Gas (LNG) tank systems of an LNG plant in Taiwan
- The results of this assessment will be used as the basis for applying an exemption from internal LNG tank periodic inspection

# I、Introduction (2 of 2)

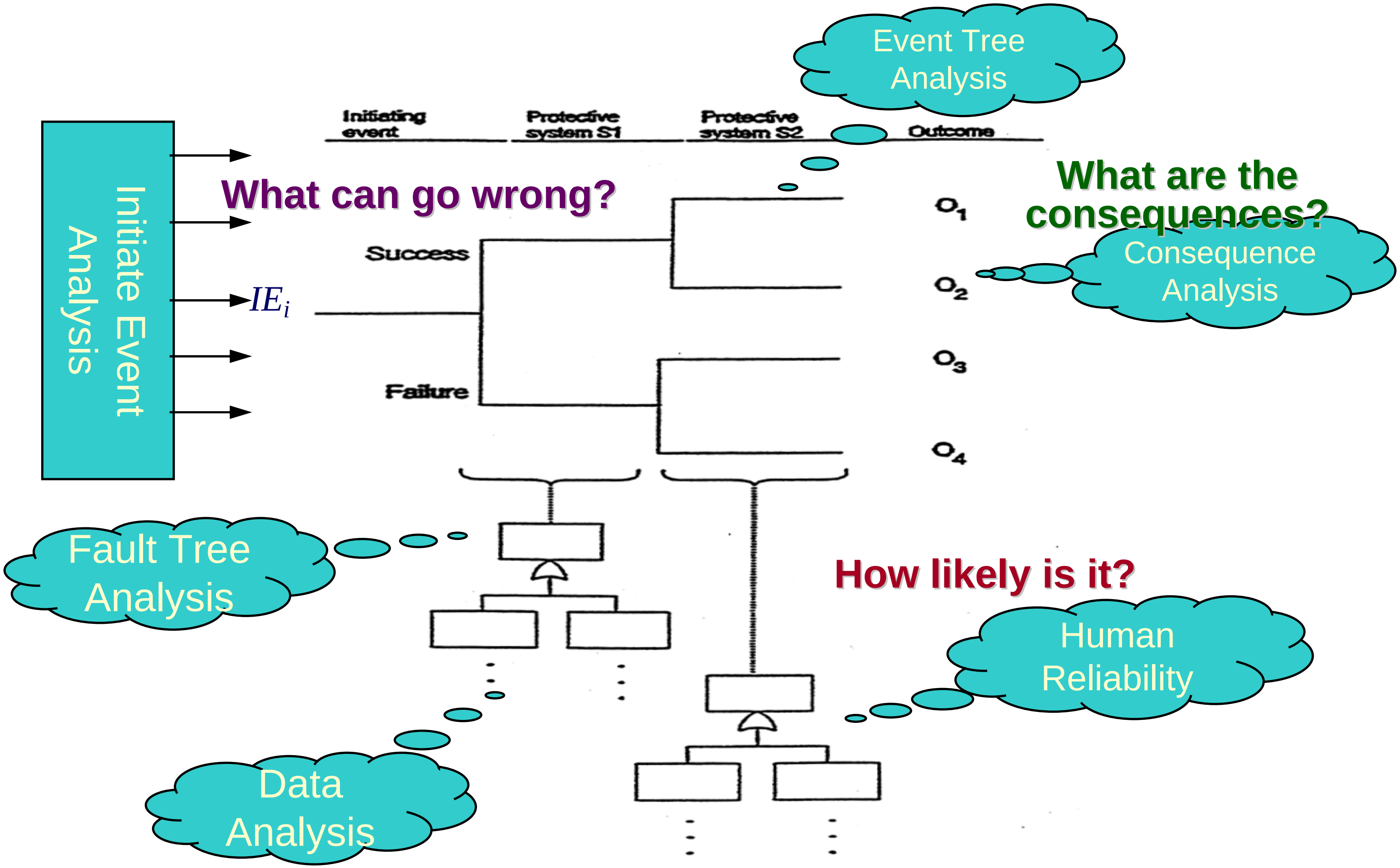
Bird's eye view of LNG plant


In-ground LNG tank

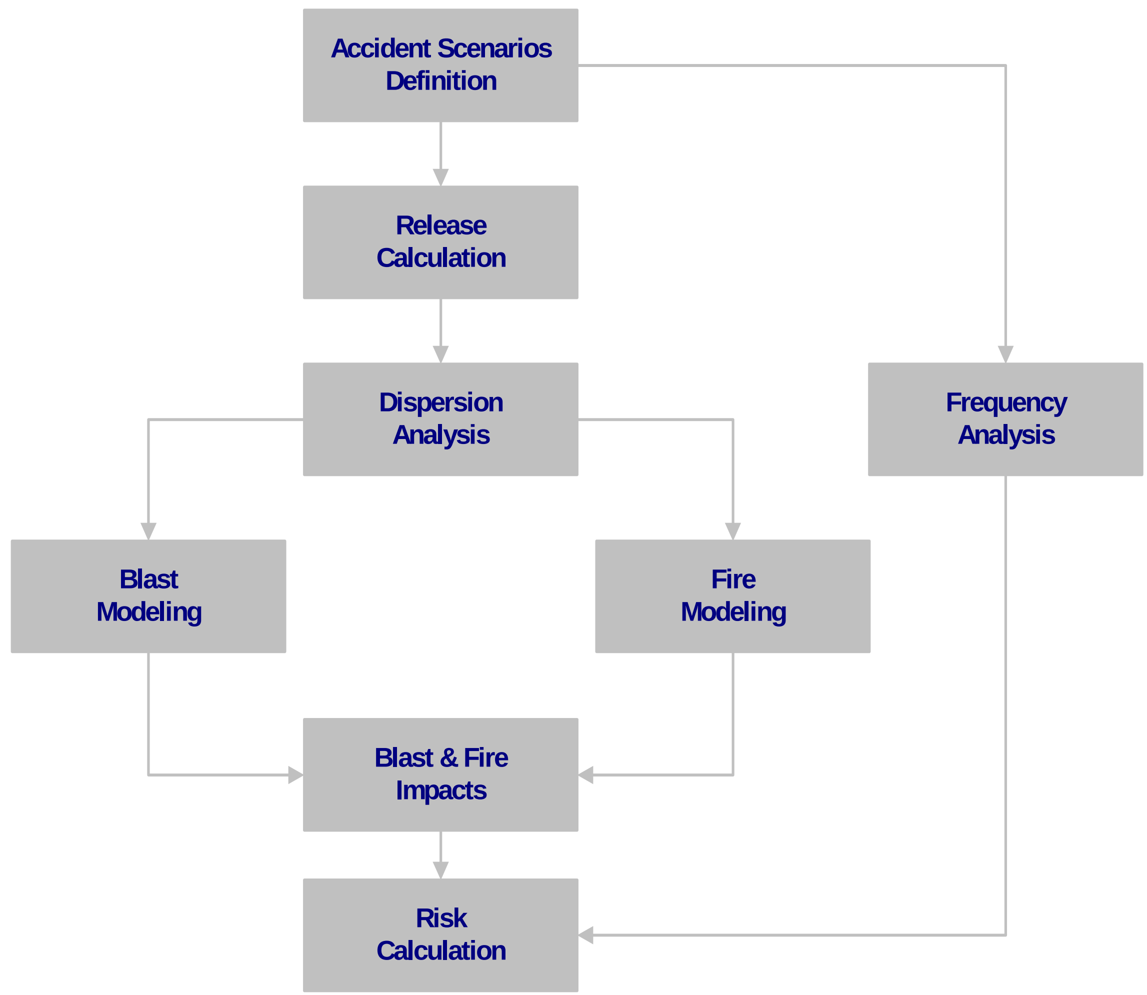
# II、 Methodology(1 of 3)

- A scenario-based approach to QRA was used in this study. It involves the identification of scenarios (i.e., answer to the question “what can go wrong?”), analysis of the scenario frequencies (i.e., answer to the question “what is the likelihood?”), and evaluation of the consequence/damage (i.e., answer to the question “what is the consequence/damage?”).

# II、 Methodology(2 of 3)



# II、 Methodology(3 of 3)




Analysis process for the QRA of an LNG Storage Tank system

# III、Assessment Process - Initiate Event (1 of 2)

- **Source of initiate events**
  - Leakage at auxiliary piping of in-ground LNG tank including Send Out pipes、unloading pipes、Bottom Spray pipes、Boil Off Gas pipes and Initial Cooling Down pipes
  - Stainless steel membrane of in-ground LNG tank breaks due to fatigue of welding or corrugated zone
  - Stainless steel membrane of in-ground LNG tank breaks due to abnormal pressure regulation of Inner Barrier Space (IBS) or malfunction of tank Heater System and Groundwater Drainage System

# III、Assessment Process - Initiate Event (2 of 2)

- **Frequency analysis of initiate events**
  - Leakage frequencies of auxiliary piping are analyzed with Failure Modes, Effects and Criticality Analysis.
  - Frequencies of stainless steel membrane of in-ground LNG tank breaks due to fatigue of welding or corrugated zone are analyzed with Probabilistic Fracture Mechanics Analysis
  - Frequencies of abnormal pressure regulation of Inner Barrier Space (IBS) 、malfunction of tank Heater System and malfunction of Groundwater Drainage System are analyzed with Fault Tree Analysis

# III、Assessment Process - Release Calculation

- Take 3 kinds of hole size in piping into consideration - 10mm、25mm and 70mm diameter hole sizes
- Use mean crack length predicted in Probabilistic Fracture Mechanics Analysis as hole size of membrane
- Use orifice model to calculate the release rate of LNG /NG from pipe to free space and from inner storage space to Inner Barrier Space (IBS) of tank

# III、Assessment Process - Event Tree Analysis (1 of 3)

- The event scenario is characterized by the section from which it releases, the size of the hole, the operating status of the section, the status of process isolation, the status of ignition (immediate, delayed, or un-ignited), the status of fire suppression, the status of fire/explosion escalation

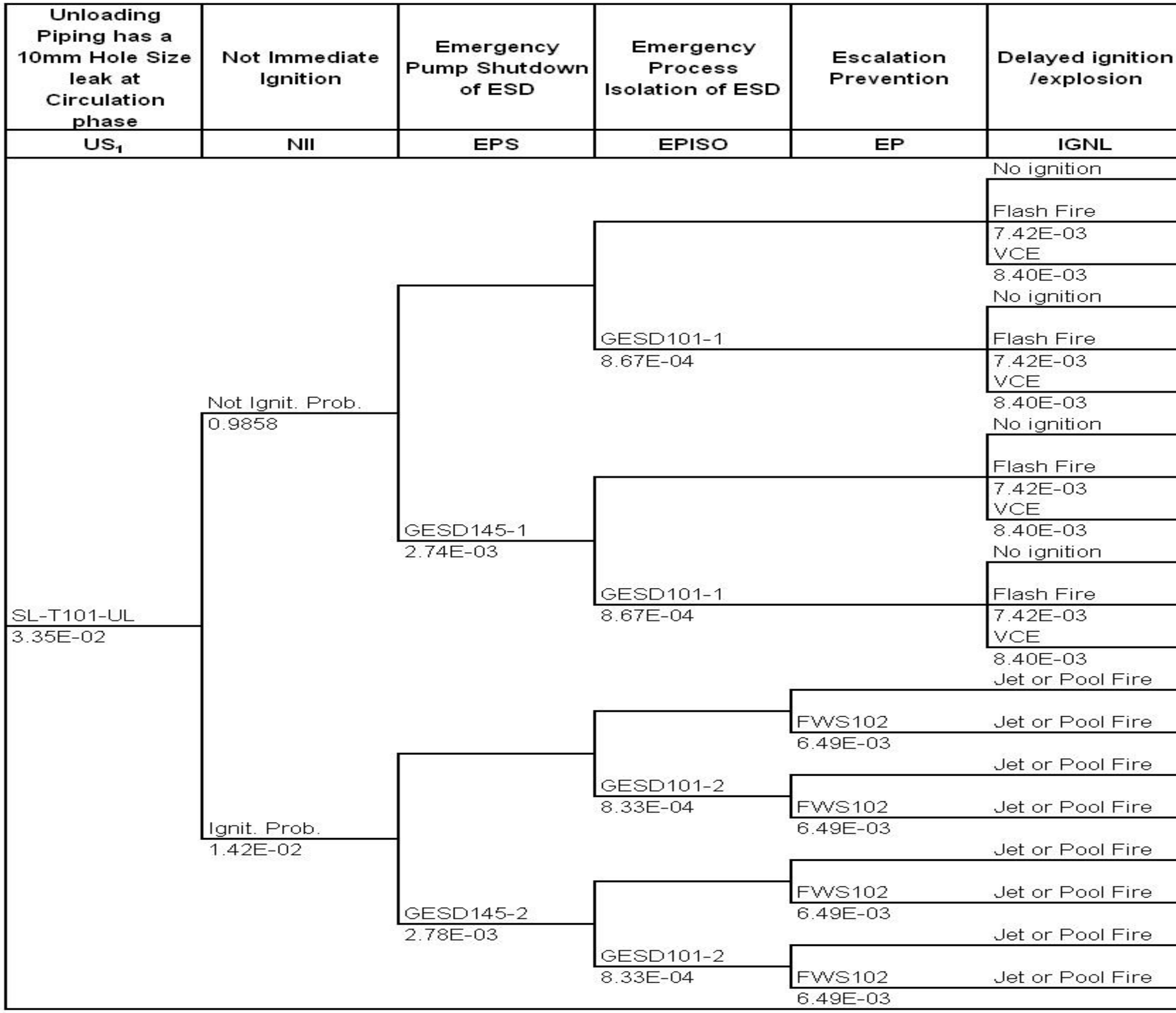
  (Weather conditions such as wind direction, wind speed, atmospheric stability, temperature, and humidity are took into consideration in consequence analysis)

- Fault tree analysis is used to estimate the system success/failure probabilities at selected event tree nodes

# III、Assessment Process - Event Tree Analysis (2 of 3)

- **Fault trees developed for modeling system response**
  - Malfunction of Emergency Shut Down System
  - Malfunction of Emergency Isolation System
  - Malfunction of Dry Chemical System
  - Malfunction of  Fire Water System
  - Malfunction of methane Online Monitor System

# III、Assessment Process - Event Tree Analysis (3 of 3)

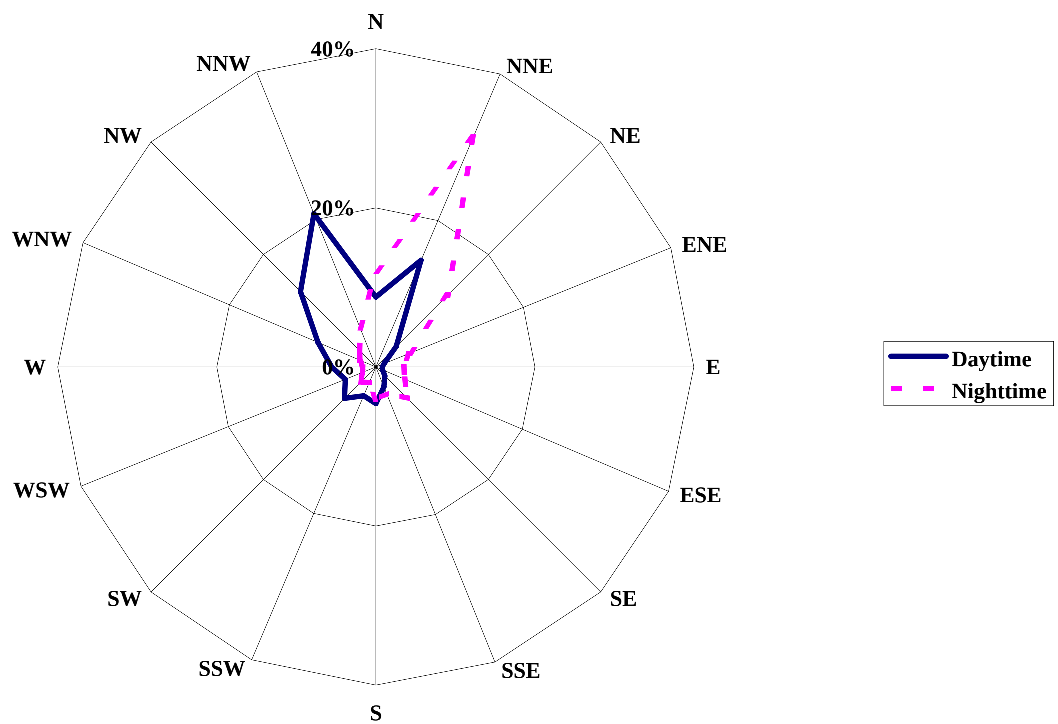



| SEQ # | SEQUENCE DESCRIPTOR | PDS # | FREQUENCY |
|---|---|---|---|
| 1 | US$_1$ | OK | 3.30E-02 |
| 2 | US$_1$IGNLF | FF | 2.45E-04 |
| 3 | US$_1$IGNLV | VCE | 2.77E-04 |
| 4 | US$_1$EPISO | OK | 2.86E-05 |
| 5 | US$_1$EPISOIGNLF | FF | 2.12E-07 |
| 6 | US$_1$EPISOIGNLV | VCE | 2.41E-07 |
| 7 | US$_1$EPS | OK | 9.05E-05 |
| 8 | US$_1$EPSIGNLF | FF | 6.71E-07 |
| 9 | US$_1$EPSIGNLV | VCE | 7.60E-07 |
| 10 | US$_1$EPSEPISO | OK | 2.12E-06 |
| 11 | US$_1$EPSEPISOIGNLF | FF | 1.57E-08 |
| 12 | US$_1$EPSEPISOIGNLV | VCE | 1.78E-08 |
| 13 | US$_1$NII | JPF | 4.76E-04 |
| 14 | US$_1$NIIEP | JPF | 3.09E-06 |
| 15 | US$_1$NIIEPISO | JPF | 3.96E-07 |
| 16 | US$_1$NIIEPISOEP | JPF | 2.57E-09 |
| 17 | US$_1$NIIEPS | JPF | 1.32E-06 |
| 18 | US$_1$NIIEPSEP | JPF | 8.58E-09 |
| 19 | US$_1$NIIEPSEPISO | JPF | 1.58E-08 |
| 20 | US$_1$NIIEPSEPISOEP | JPF | 1.02E-10 |

# III、Assessment Process - Consequence Analysis (1 of 6)

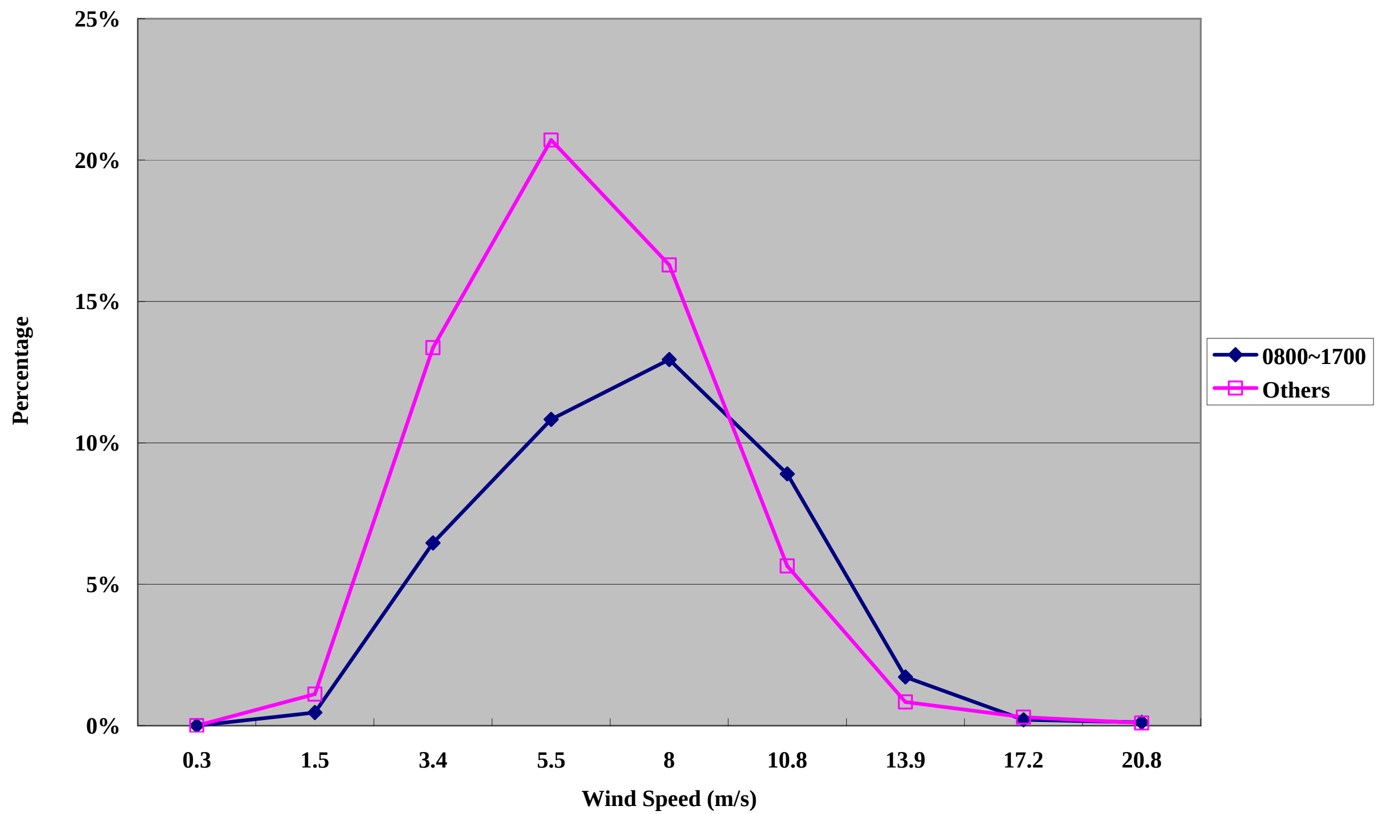
- Collect meteorological data more than one year to evaluate the probability distribution of wind direction and speed
- Collect information about population of nearby town and numbers of employees during daytime and nighttime
- Consequence of each event tree sequence is evaluated with TRACE software of Safer©

# III、Assessment Process - Consequence Analysis (2 of 6)



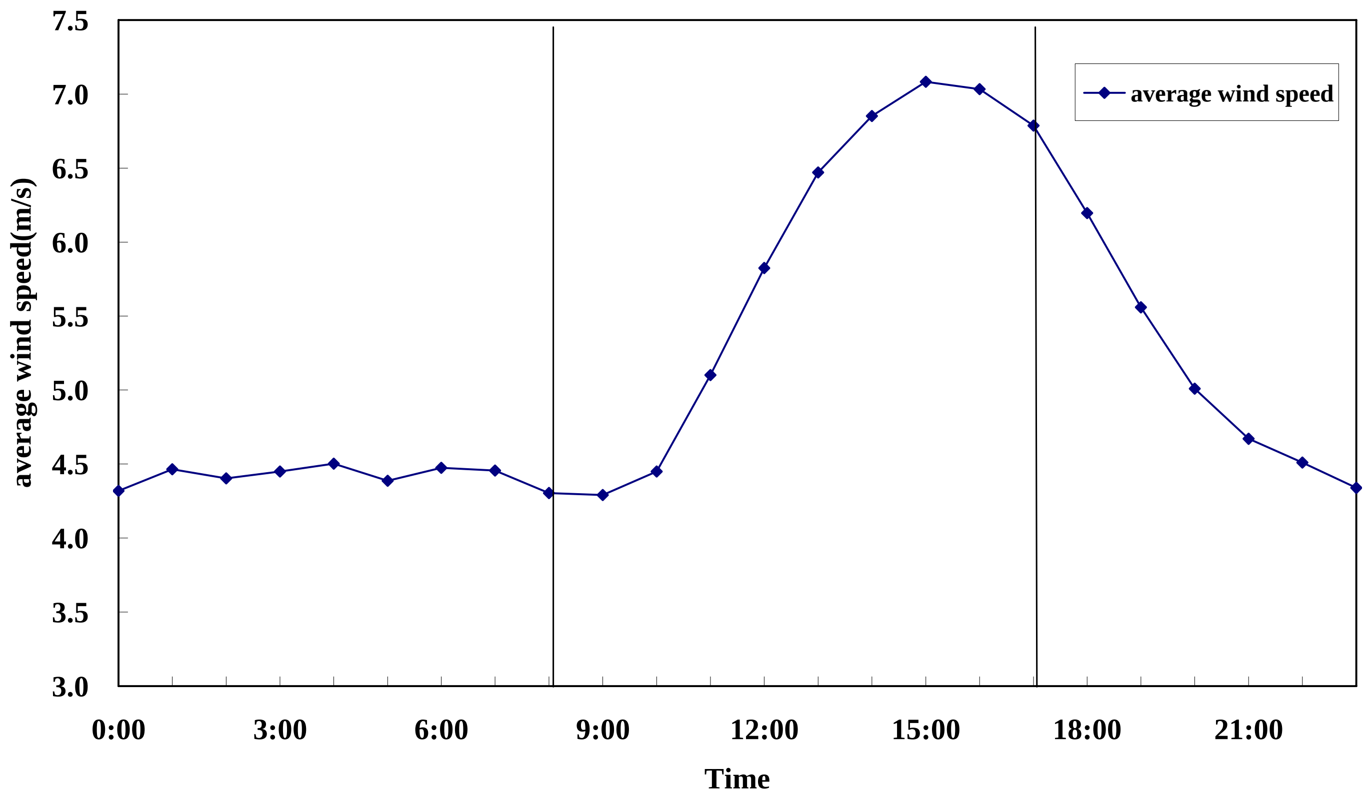

Wind direction distribution during winter around target LNG plant

# III、Assessment Process - Consequence Analysis (3 of 6)



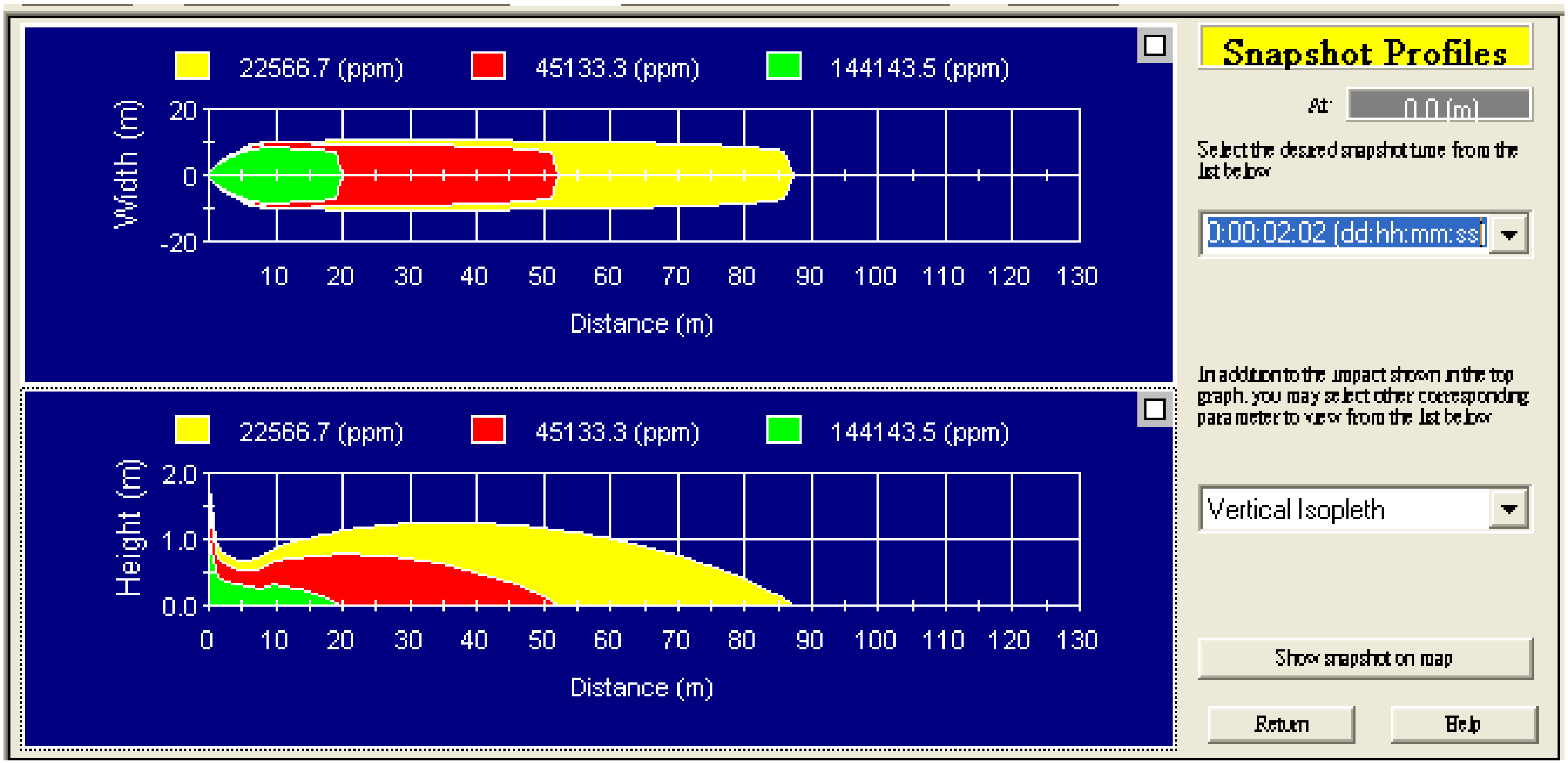

Wind speed distribution around target LNG plant

# III、Assessment Process - Consequence Analysis (4 of 6)




Average wind speed during one day

# III、Assessment Process - Consequence Analysis (5 of 6)




Dispersion simulation in case of Unloading Pipe with a 70mm hole, wind stability grade F, wind speed 1.6m/sec

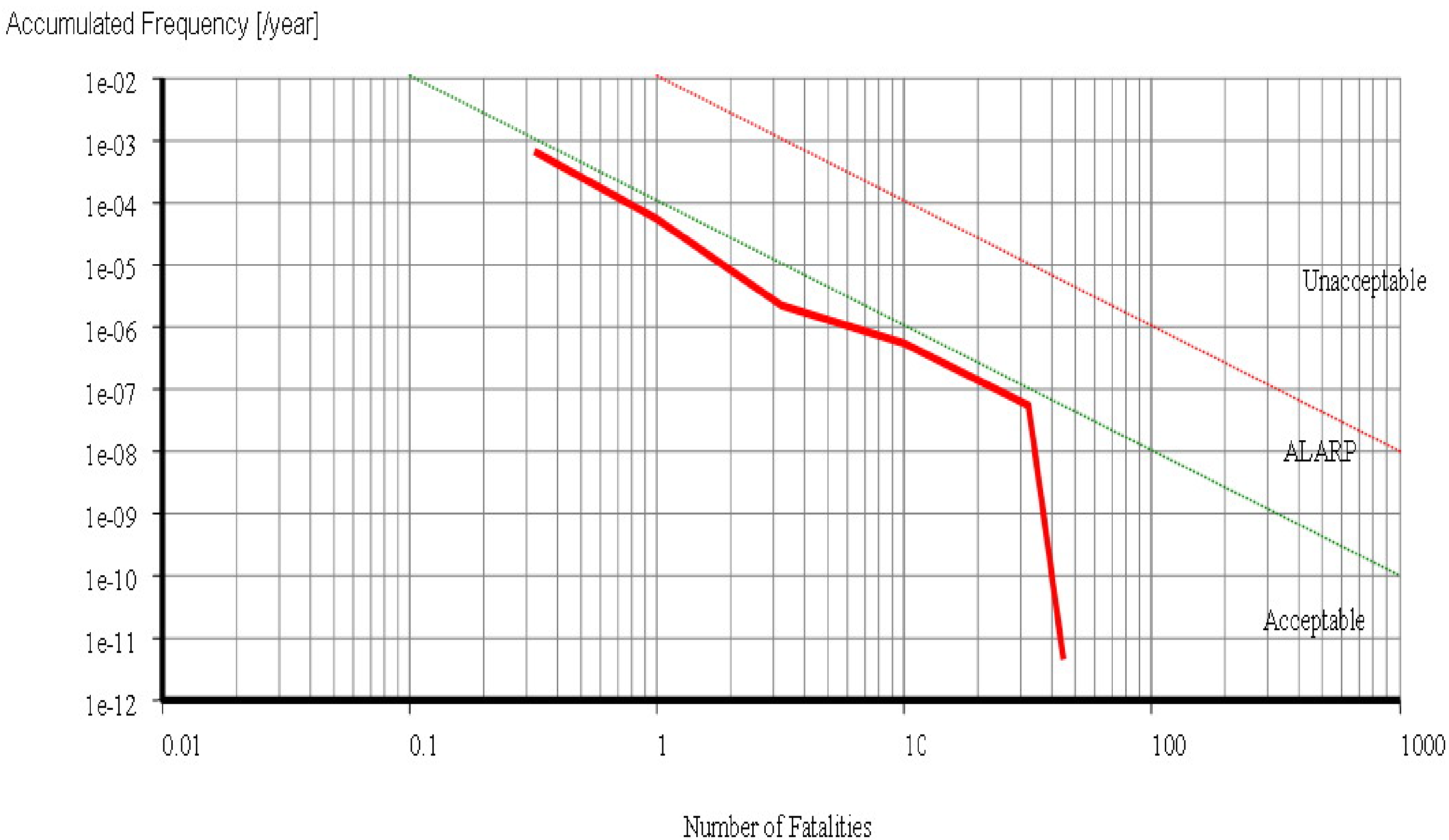
# III、Assessment Process - Consequence Analysis (6 of 6)


Dispersion simulation in case of Unloading Pipe with a 70mm hole, wind stability grade F, wind speed 1.6m/sec

# III、Assessment Process - Risk Analysis (1 of 2)


Individual risk profile caused by LNG tanks system

# III、Assessment Process - Risk Analysis (2 of 2)




Societal Risk F-N curve due to LNG tank systems

(ALARP：As Low As Reasonably Practical)

# Ⅳ、 Conclusions

- The application of QRA technique on LNG plant can provide the quantified risk index and also shows the consequence outcomes with direct visual image
- The influence of LNG plant accident on community surrounding the LNG plant becomes clear without any obscurity.
- Based on result of this study, the Taiwan's Council of Labor Affairs (TCLA) had granted the Taiwan Chinese Petroleum Corp. (TCPC) with 2 additional years exemption from internal inspection of LNG tanks in March 2007

***Thanks for your attentions!***