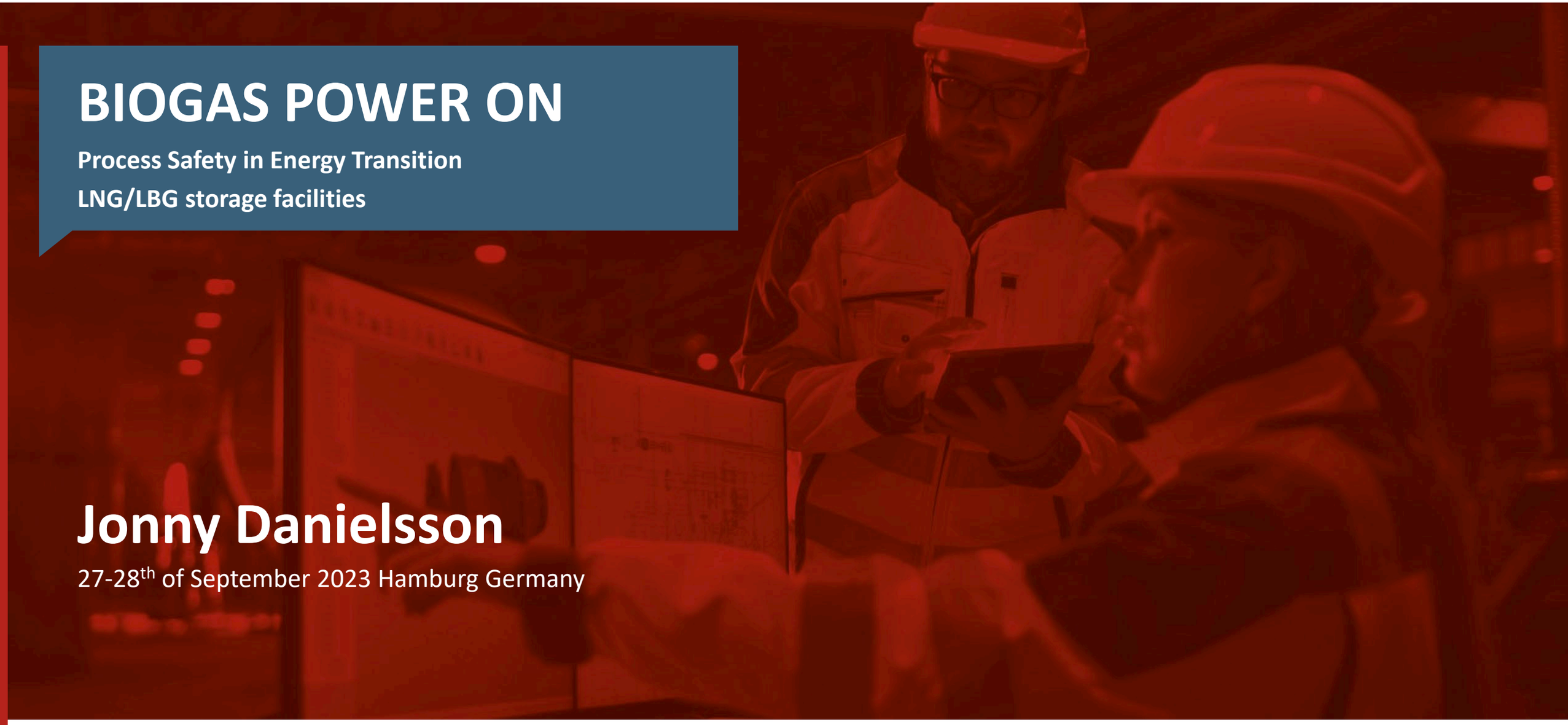
GEXCON

BIOGAS POWER ON

Process Safety in Energy Transition

LNG/LBG storage facilities



Jonny Danielsson

27-28th of September 2023 Hamburg Germany

Tabel of Content

1. Who We Are

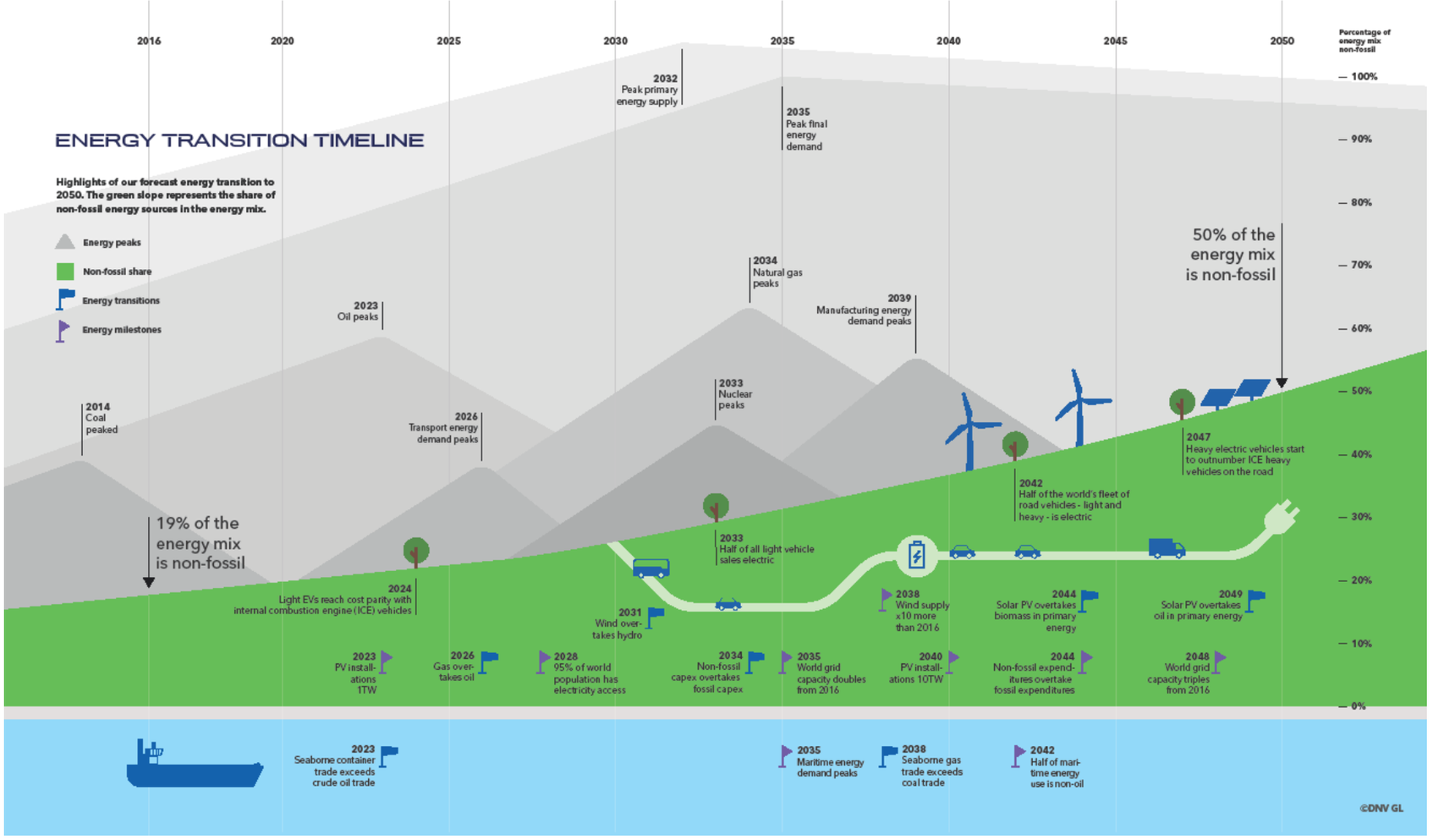
https://www.gexcon.com/products-services/process-hazard-analysis/

Gexcon is a global company fully owned by Longship with 170+ employees in Europe, America and Asia.

Our Services

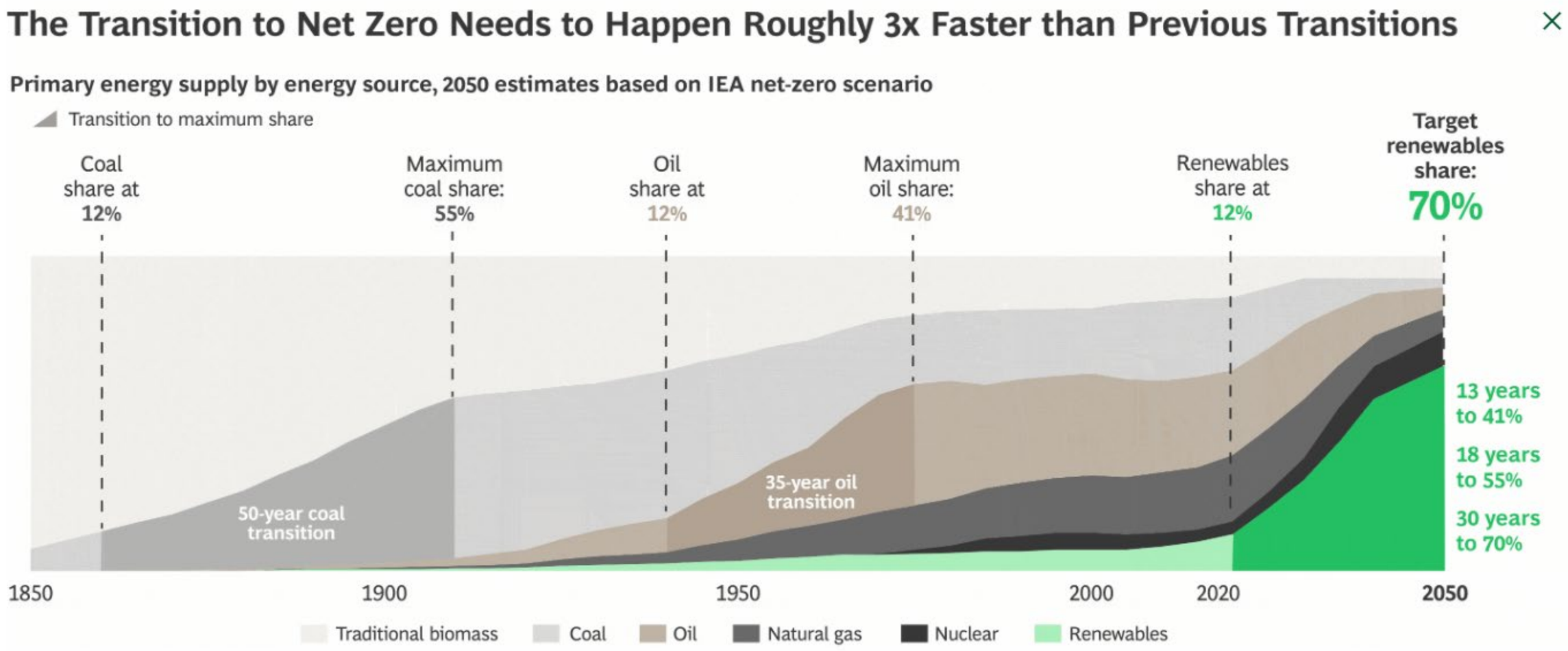
2. Energy Transition Timeline

DNV GL, 10 September 2018, https://eto.dnvgl.com



2.1 Now Acceleration is needed

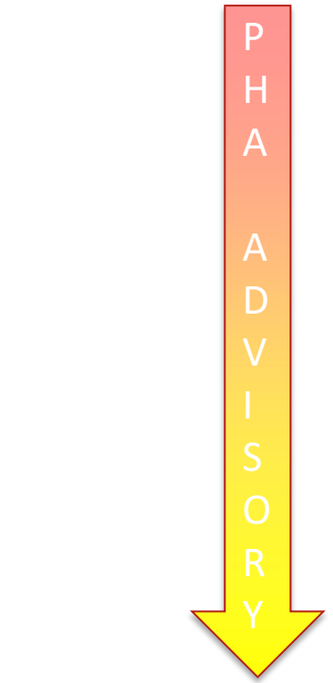
BCG https://www.bcg.com/industries/energy/energy-transition/blueprint



3. Use the same PHA methods already developed

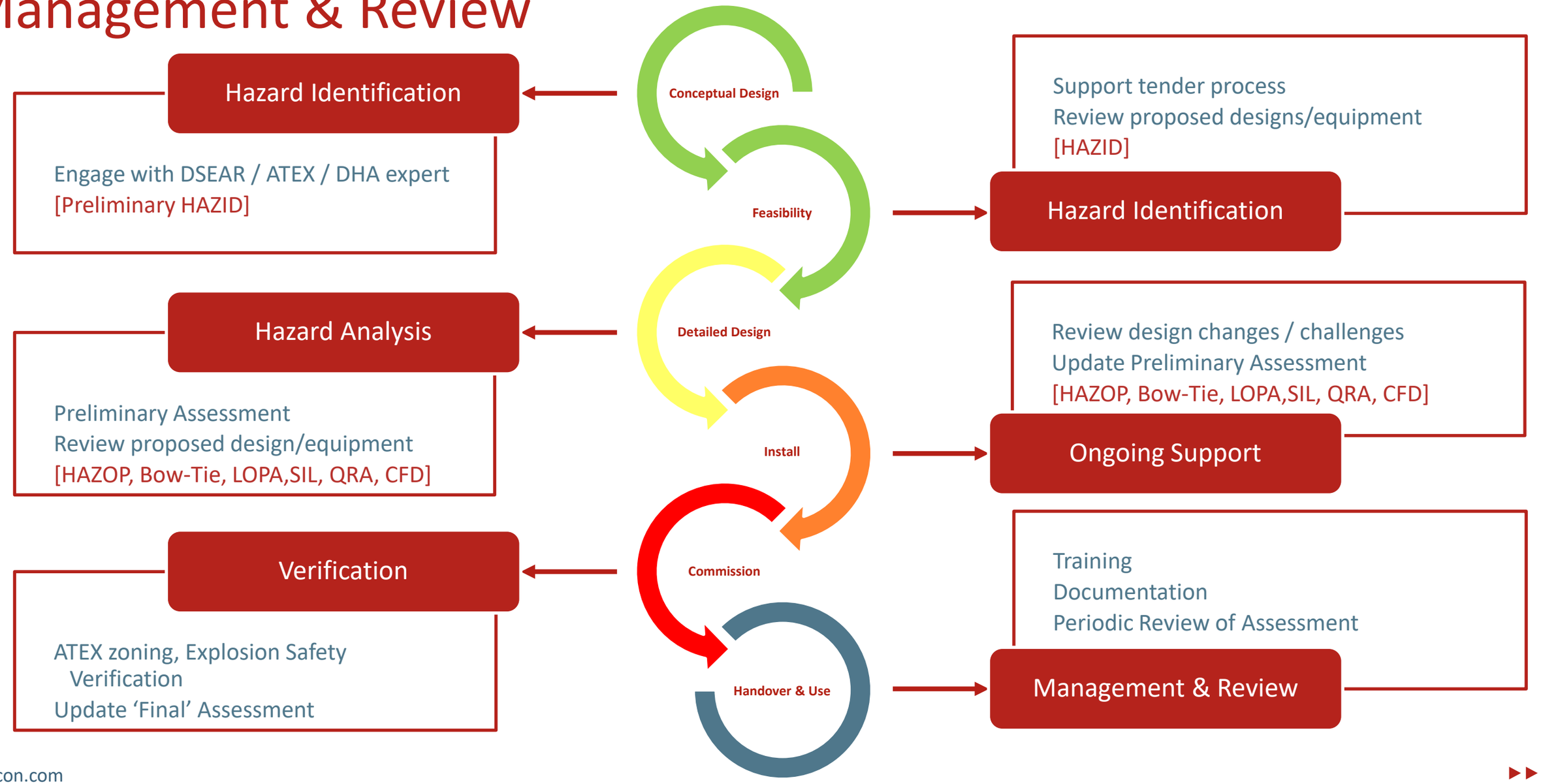
Consultancy Services

- Pre-HAZID
- HAZID
- HAZOP
- LOPA
- Bow-Tie
- QRA Quantified Risk Assessment
- FLACS CFD Simulation
- ATEX zone classification
- Advise on all aspect of process safety during the whole process in green field projects or retrofit of brown field LNG to green LBG storage facility.
- To complete the predictive and technical aspect of the pre-operational safety report for the site as an upper tier establishment under Seveso or COMAH regulation



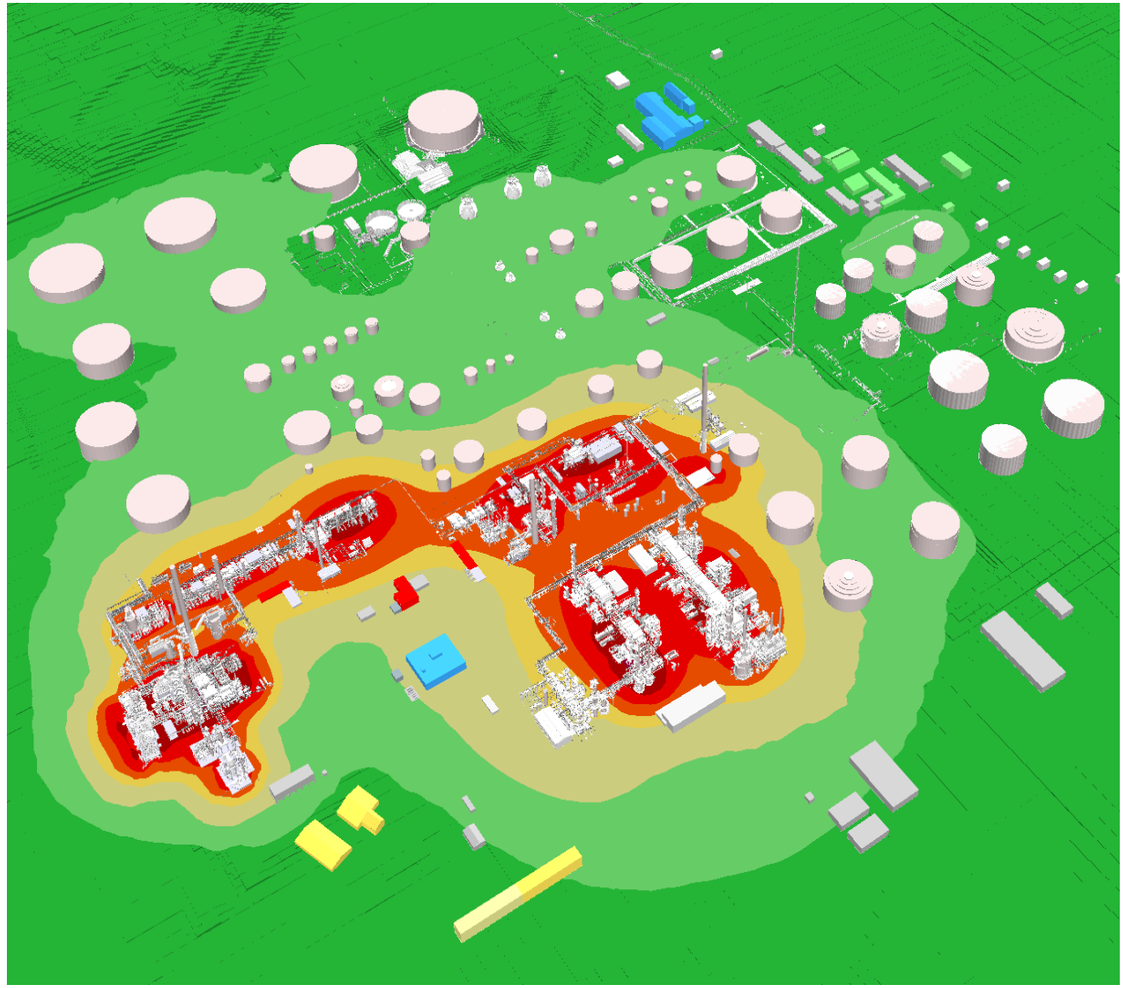
O Mayor Accident
Better Project Cost and timeline control

3.1 Process Safety in New or Transition Project Lifecycle Management & Review

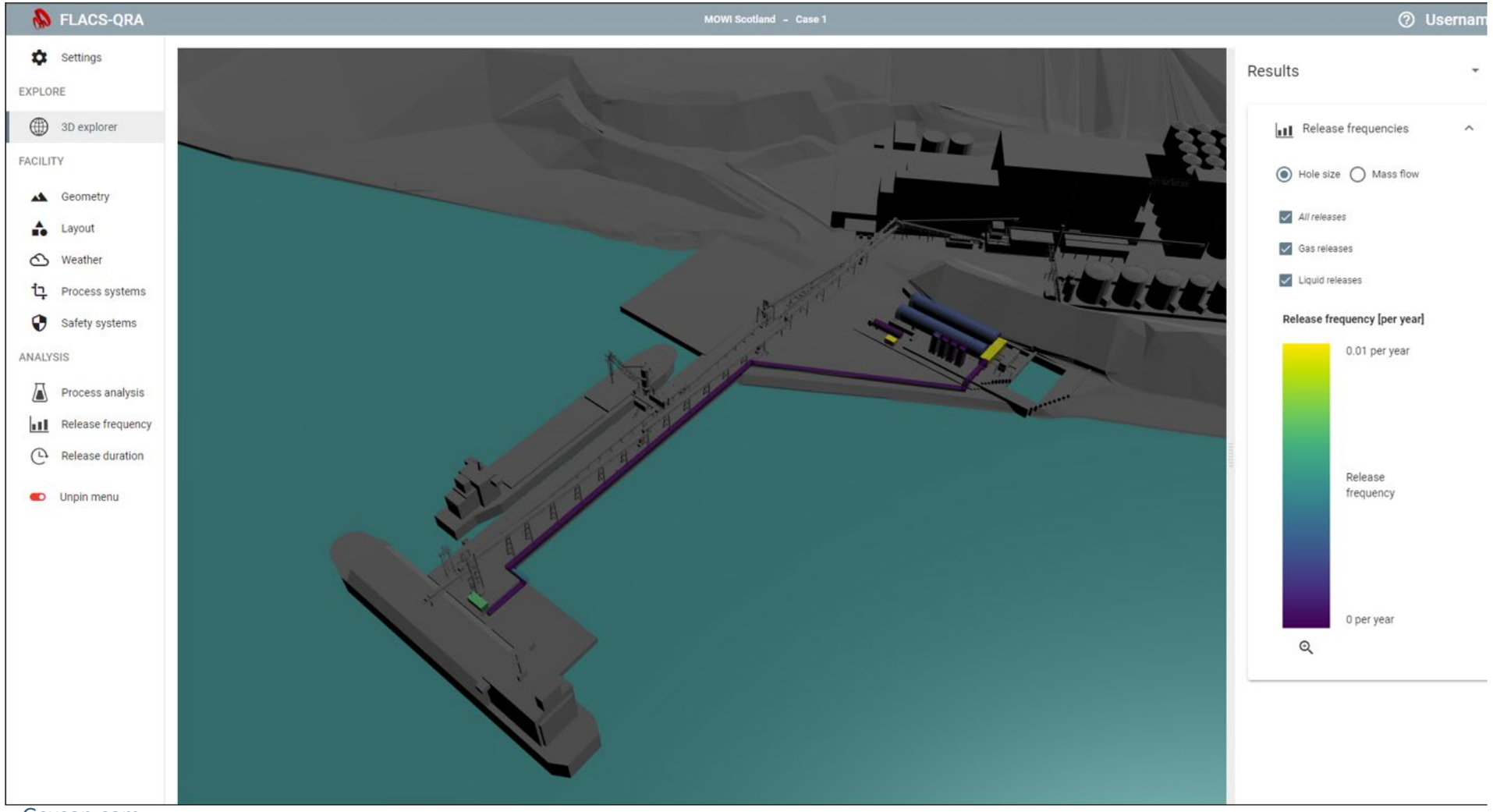


4. FLACS- 3D QRA features

- Integrates all parts of a QRA study
  - System description
  - Release frequency calculation
  - Dispersion consequence modelling
  - Ignition probability calculation
  - Fire consequence modelling
  - Explosion consequence modelling
  - Risk modelling

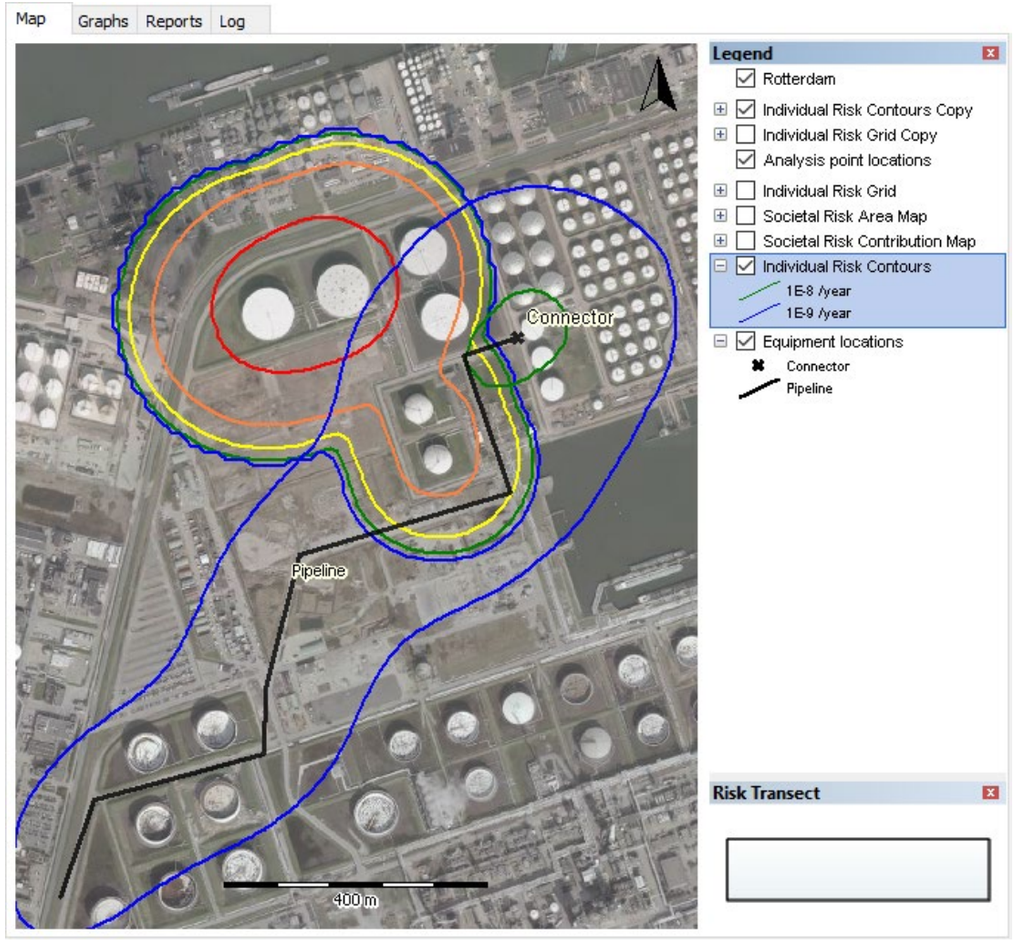


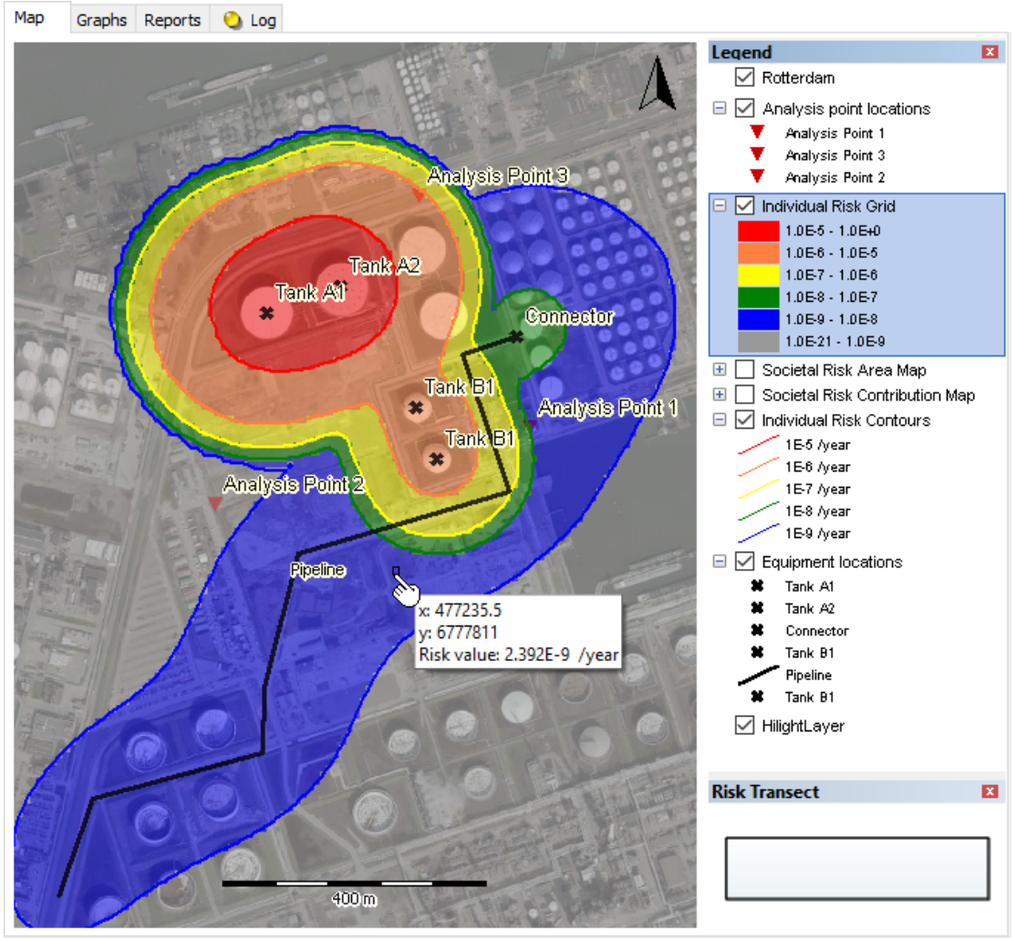
4.1 FLACS- 3D QRA features



4.2 2D QRA FLACS Riskcurve

QRA results are often locational: shown as Iso Risk Contours





4.3 Accumulating risk results

Geographic oriented (locational) risks can be summed up

- ***QRA results are often locational: shown as Iso Risk Contours***

- Commonly used: surrounding contour
- Surrounding contour neglects the fact that $0.5*10^{-6}$ + other risk $0.5*10^{-6}$ would create $1*10^{-6}$
- Correct method: sum up risk grid (spatially distributed risk values in x, y raster)
- Requires identical geographic coordinate projection system

- RISKCURVES allows to save all risk grids shown (with projection system)
- Already allows combining / showing specific selected scenario sets
- Request: combine imported grids with calculated grids

5. Definition of a Hazardous Area

- Hazardous area: an area where an explosive atmosphere can exist in such an extent that it requires specific measures in order to protect personnel against the dangers of explosions and thus results in the need for area classification.

- Flammable material does **NOT** automatically yield a hazardous zone (Ex Zone)

- However, a hazardous explosive atmosphere does result in hazardous zones (Ex Zones) and the need for hazardous area classification

5.1 What does Hazardous Area Classification Influence?

- The frequency of occurrence of explosive atmospheres is a component of the risk assessment

- The design of an installation
  - Number of possible points of release, location of equipment, physical barriers, doors and openings
  - Ventilation requirements

- Safe operation of an installation
  - Shut down philosophy, maintenance activities

- Procurement decisions
  - Equipment that will be used in hazardous areas

5.2 Hazardous Area Classification Standards

- **Gases and Vapours:**
  - **EN 60079-10-1**: Classification of areas – Explosive gas atmospheres

- **Dust and Fibres:**
  - **EN 60079-10-2**: Classification of areas - Combustible dust atmospheres

5.3 Zones – Definitions (Gas / Vapour)

- **Zone 0**

  …. a place in which an explosive atmosphere consisting of a mixture with air of dangerous substances in the form of gas, vapour or mist is present continuously or for long periods or frequently.

- **Zone 1**

  ..... is likely to occur in normal operation occasionally.

- **Zone 2**

  ..... is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

5.4 Zones – Definitions (Gas / Vapour)

- **Zone 2 NE**
  - An additional zone, a Zone of Negligible Extent (NE) can be classified in line with EN 60079-10-1
  - This is a zone created by a flammable cloud so small that, if ignited, the pressure effects would be of negligible consequence
  - Typically classified due to either a small release, good ventilation, or a combination of both

5.5 EN 60079-10-1, Table D.1 - Practical Guide

Grade of release	Effectiveness of Ventilation						
	High Dilution			Medium Dilution			Low Dilution
	Availability of ventilation						
	Good	Fair	Poor	Good	Fair	Poor	Good, fair or poor
Continuous	Non-hazardous (Zone 0 NE)[a]	Zone 2 (Zone 0 NE)[a]	Zone 1 (Zone 0 NE)[a]	Zone 0	Zone 0 + Zone 2	Zone 0 + Zone 1	Zone 0
Primary	Non-hazardous (Zone 1 NE)[a]	Zone 2 (Zone 1 NE)[a]	Zone 2 (Zone 1 NE)[a]	Zone 1	Zone 1 + Zone 2	Zone 1 + Zone 2	Zone 1 or zone 0[c]
Secondary[b]	Non-hazardous (Zone 2 NE)[a]	Non-hazardous (Zone 2 NE)[a]	Zone 2	Zone 2	Zone 2	Zone 2	Zone 1 and even Zone 0[c]

[a] Zone 0 NE, 1 NE or 2 NE indicates a theoretical zone which would be of negligible extent under normal conditions.

[b] The zone 2 area created by a secondary grade of release may exceed that attributable to a primary or continuous grade of release; in this case, the greater distance should be taken.

[c] Will be zone 0 if the ventilation is so weak and the release is such that in practice an explosive gas atmosphere exists virtually continuously (i.e. approaching a 'no ventilation' condition).

'+' signifies 'surrounded by'.

Availability of ventilation in naturally ventilated enclosed spaces shall never be considered as good.

6. FLACS CFD 50 years of advanced R&D has led to the best modelling software globally

1970s

1972 Following several explosion accidents, Dust explosion research started at Christian Michelsen Institute (CMI)

1974 Flixborough disaster results in 28 deaths – with many more injured

1978 Start of gas explosion research as part of the program "Safety at the Continental Shelf"

1980s

1986 First version of FLACS (FLACS-86) released to Gas Safety Program sponsors

1988 The Piper Alpha accident sparks the need for proper understanding of risk and risk mitigation

1989 Establishment of Gexcon as a consulting department for FLACS services

1990s

1993 Development of new FLACS features: Dispersion, Far Field Blast, Water Spray

1996 FLACS commercially available

1998 Gexcon AS was established to sell FLACS & FLACS services

2000s

2000 Christian Michelsen Research (CMR) eProcess Safety Department incl. R&D and Labs merges with Gexcon

2008 Established Gexcon UK

2008 Established Gexcon US

2010s

2011-19 Global expansion in India , China, Indonesia, Australia, UEA, France and Netherlands

2016 Extended Portfolio; FLACS Fire, FLACS Risk, Stormfjord, FLACS VR/AVR Hub Safety

2018 Gexcon entered into an agreement with Shell to be the sole supplier of their software FRED, Shepherd and PIPA

2019 Gexcon acquired the complete rights to the software tools EFFECTS and RISKCURVES from TNO

2019 Hydrogen safety defined as a strategic growth area

2020s

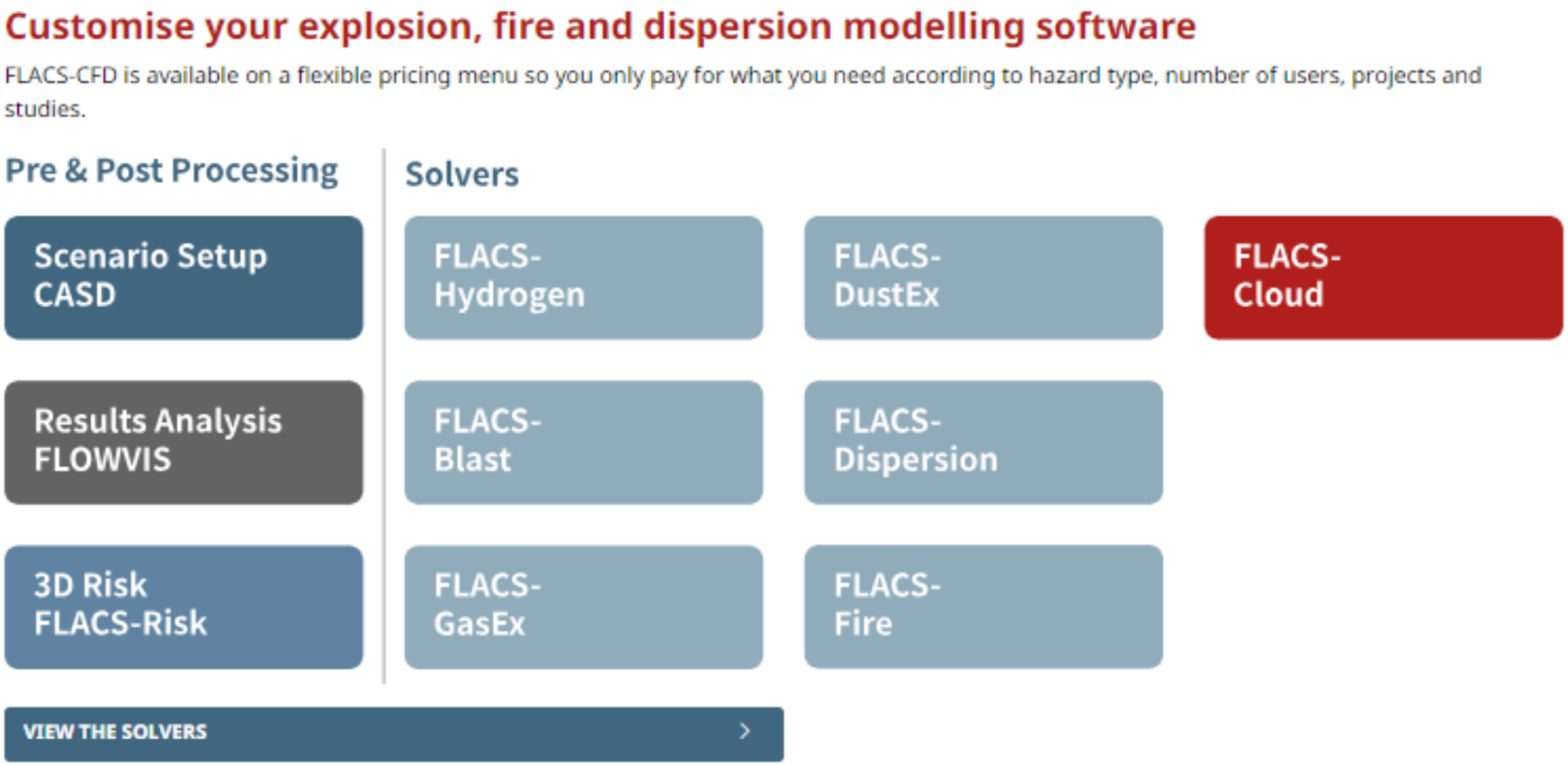
2020 Web based products & services based upon new digitalization strategy

Development of tools to continue reducing accidents and contribute to the energy transition

Established Gexcon Sweden

6.1 FLACS-CFD 22 Latest Version

FLACS-CFD Consequence Modelling Software for safety professionals (gexcon.com)



6.2 The FLACS-CFD Modules

CFD

Dispersion (incl. LNG &LBG)

- FLACS-Dispersion allows the simulation of natural and forced ventilation as well as loss of containment (leaks) and dispersion of dangerous substances

Example:

- Modelling release of toxic ammonia gas from refrigeration units in the food industry
- Simulation of pool evaporation and gas dispersion for an LNG release as well as for LBG
- Modelling gas releases in oil & gas, including effect of ventilation on cloud buildup

Gas explosions

- FLACS-GasEx allows the simulation of vapour cloud explosions. It is used extensively across industries to understand the consequences, both for risk assessment, design input and design specifications

Example:

- Verify structural integrity (valid for all industries)
- Identifying various scenarios contributing to an explosion in an accident investigation
- Modelling consequences of gas explosions at chemical production plants

Dust explosions

- FLACS-DustEx allows the simulation of industrial dust explosions. This is a valuable tool for engineering when optimising venting devices, suppression systems or explosion barriers

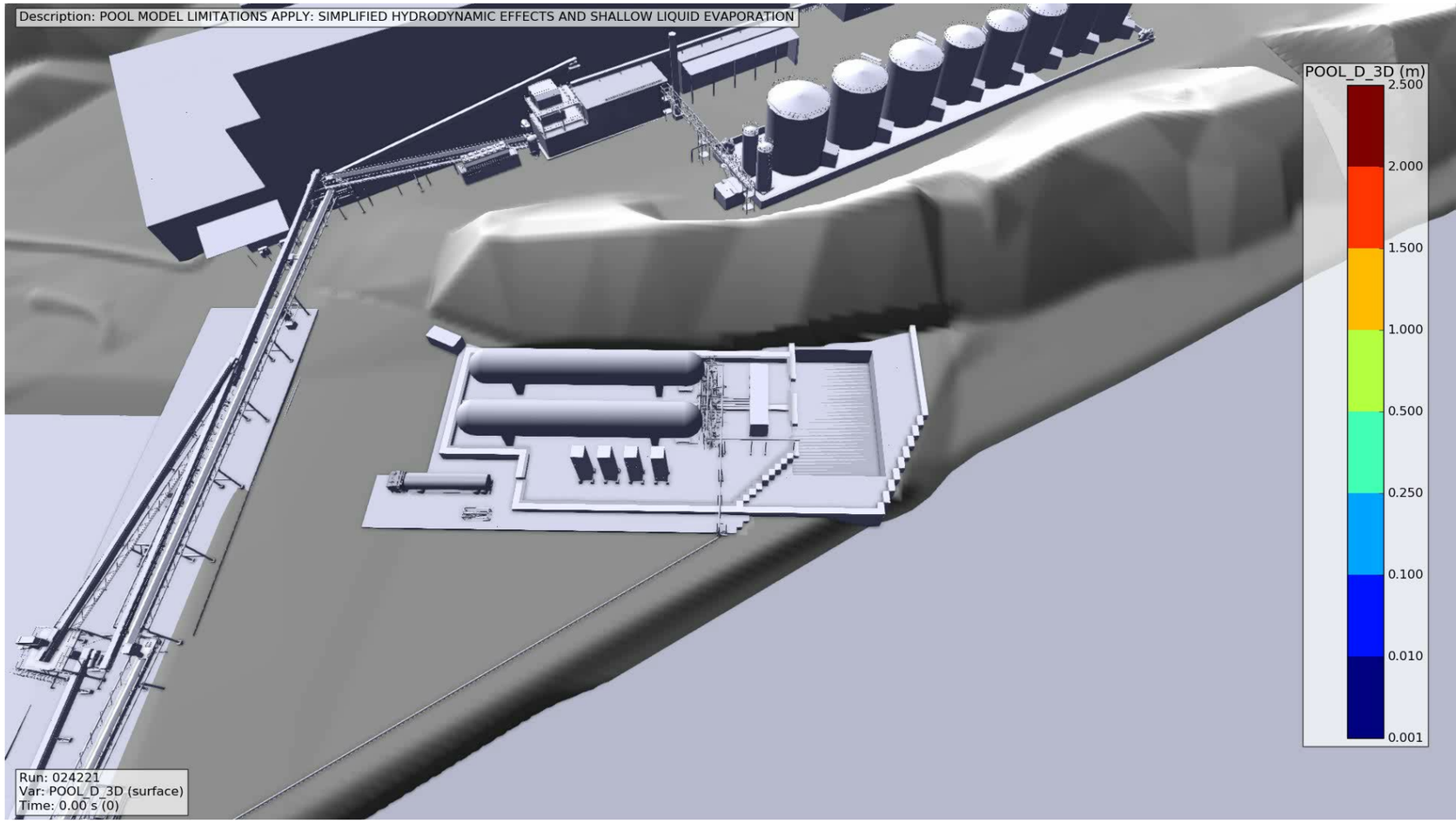
Example:

- Modelling dust explosion consequences in the food, biomass, metallurgy, chemical or pharmaceutical industry as input to cost effective mitigation measures
- Used frequently in accident investigations

7. Case Study, Pre-Operations Safety Report (Isle of Skye)

Catastrophic failure of one tank (10s)

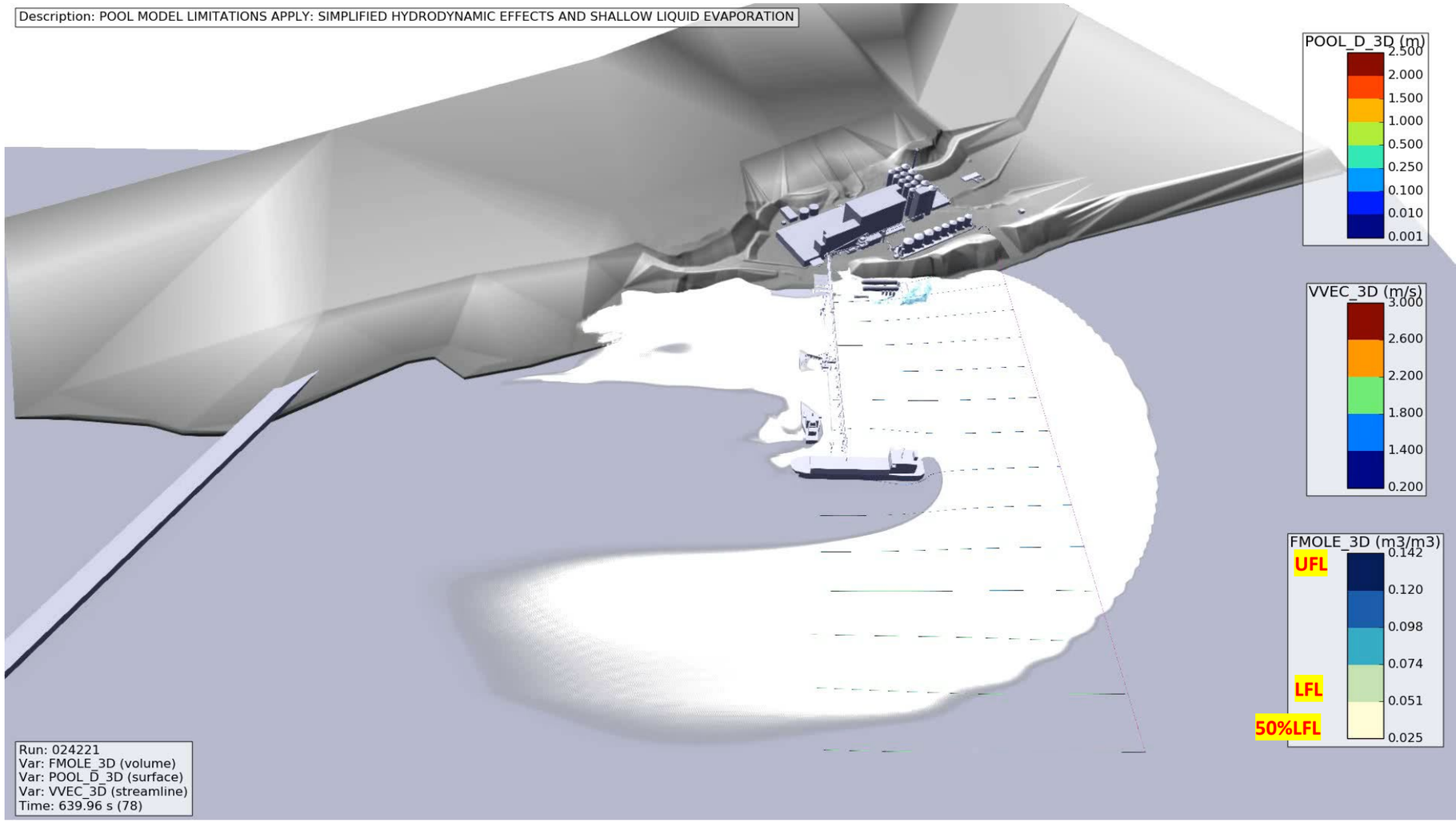
- Liquid spread after catastrophic failure (mimicked by releasing 400 ton of LNG in 10 seconds over a defined circular area in the bund.
- It should be noted that hydrodynamics effects are simplified in the model, where for example, sloshing and liquid breaking are not accounted for.
- While the model provides a reasonable prediction of the liquid spread in such event, it is sensitive to the input such the finite duration of contents release for example.
- Note that the bunding area is not inclined and hence draining is slower.



7.1 Case Study, Pre-Operations Safety Report (Isle of Skye)

Catastrophic failure of one tank (10s)

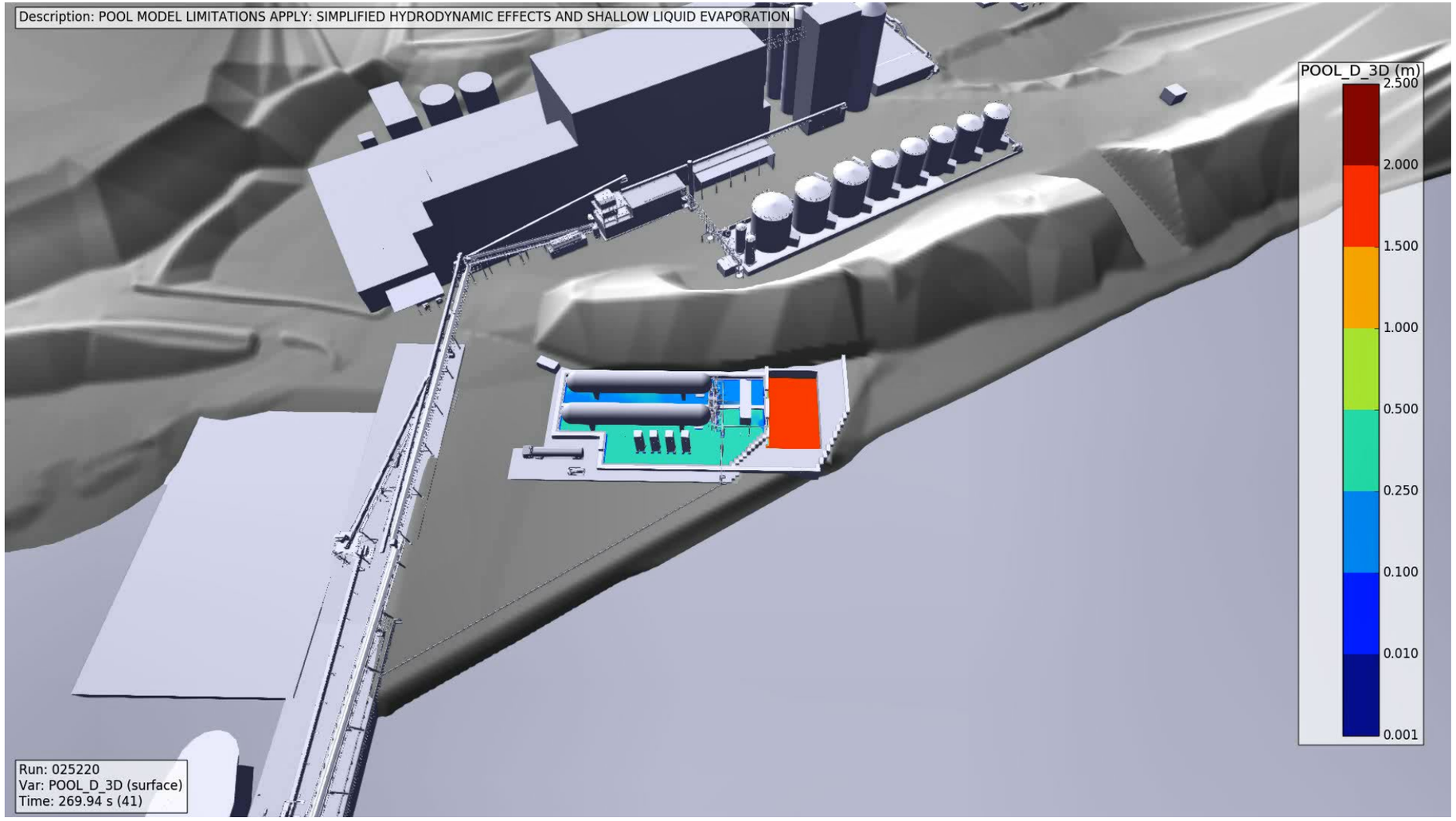
- Wind speed is 2 m/s blowing from West to East.
- The LNG spill outside the bunding area, over the shore and on the sea, created a large base area for evaporation generating a large flammable cloud spreading over a large area. The vapour(50% LFL) reached the boundary domain on the north side (sea). Simulations were run for 20 minutes, however the cloud can go further than the shown areas.
- Note that evaporation equations are for shallow liquid. Therefore evaporation from the deep pit can be overpredicted.



7.2 Case Study, Pre-Operations Safety Report (Isle of Skye)

Catastrophic failure of one tank (20s)

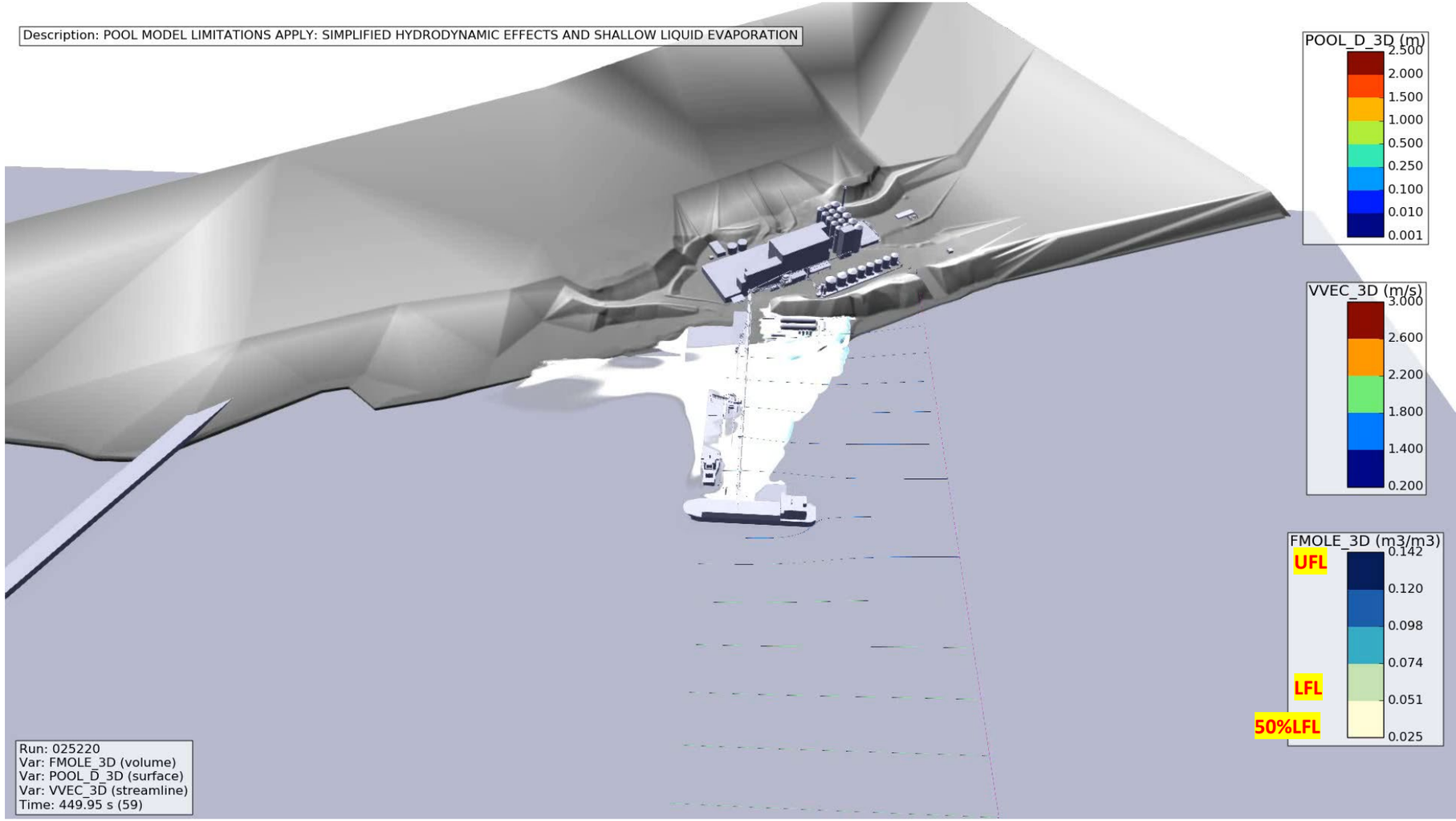
- Liquid spread after catastrophic failure (mimicked by releasing 400 ton of LNG in 20 seconds over a defined circular area in the bund.
- In this case the spill outside the bunding area compared to the 10s release is very limited.
- The spill is almost contained and slowly drained into the collecting pit. Note that the bunding area is not inclined and hence draining is slower.



7.3 Case Study, Pre-Operations Safety Report (Isle of Skye)

Catastrophic failure of one tank (20s)

- Wind speed is 2 m/s blowing from West to East.
- As in this sensitivity scenario (20s release), the liquid remains almost contained in the bunding area and therefore the evaporation area remains also contained.
- The flammable cloud (50%LFL) reaches the jetty and conveyor but is much smaller compared to 10s release.



8. Question ?

- **Our Vision and Mission**
- Our vision is to make the world a safer place.
- We work hard to be the preferred partner in dispersion, fire, and explosion safety as well as risk management to make this vision come true.

Jonny Danielsson

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Gexcon Consulting

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Stay Safe in the Energy Transition