WHEN TRUST MATTERS

External safety distances & focus areas for bunkering hydrogen in the Netherlands

Quantitative Risk Assessment (QRA) in accordance with Bevi

RH2INE Sub-study 1b, SuAc A3

09 April 2021

Overview

- Legal background & terminology
- Methodology - Land-Use Planning (LUP) approach in the Netherlands and determination of external safety distances
- Methodology - Focus areas (new concept in Environmental law 2022)
- Bunkering scenarios
- Parameters and assumptions for QRA
- Results & conclusions for external safety distances
- Results & conclusions for focus areas

Legal background & terminology (1/2)

- Determination of external safety distances & focus areas is based on national legislation and guidelines.
- The current legislation that is used to determine the acceptability of the risk an activity imposes on its environment is the decree external safety facilities (Bevi).
- The Bevi details a risk-based approach in which both the frequency and consequence of hazardous events are taken into account. A Quantitative Risk Assessment (QRA) needs to be developed.
- The Bevi details two types of risk metrics: Location-specific Individual Risk (LSIR) and Societal Risk (SR).
- The 10^{-6} per year LSIR-contour is the external safety distance to vulnerable objects (e.g. houses, hospitals, schools etc.). The SR is used to address risk of incidents involving 10 or more casualties and depends on the number of people present in the vicinity (not covered in this study)

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Legal background & terminology (2/2)

- In January 2022 a new environmental law will come into force requiring the determination of focus areas that will replace societal risk.
- Also Bevi will cease to exist and will be replaced by other laws (Bal/Bkl etc.).
- Focus areas are areas around an activity involving hazardous materials. The areas provide insight into the hazards that people indoors (without additional protective measures) can be exposed to as a result of the activity.
- Within the areas, specific construction requirements may be enforced for buildings to offer protection against fire, explosion or toxic impact to the occupants inside.
- Focus areas are also determined based on a QRA.

Methodology - LUP-approach in the Netherlands

- The methodology for a Bevi QRA is provided in the Reference Manual Bevi risk assessments (HRB).
- The HRB details standard failure scenario’s and frequencies for equipment. These are used for the QRA, which is performed using software package Safeti-NL.
- The output of the QRA is a set of location-specific risk contours on a map, showing the probability that an unprotected person present 24/7 at a specific location dies as a result of an incident from the activity.
- In this study, the risk contours for various bunkering scenarios are calculated and shown on a map with means of a QRA. The radius of the 10^{-6}/year contour is measured and represents the external safety distance to vulnerable objects.

Methodology focus areas

- Focus areas are based on the worst-case scenarios in a QRA and do not take frequency in consideration, therefore they are normally much larger than the external safety distance.
- There are three types of focus areas with the following threshold criteria:
  - Fire focus area (Jet fire / pool fire -> 10 kW/m^2)
  - Explosion focus area (vapour cloud explosion -> 0.1 bar, fireball -> 35 kW/m^2)
  - Toxic focus area (exposure to toxic concentrations -> 2.54 x LBW (~ERPG 3))
- The focus areas are calculated in this study and shown on a map. The (maximum) distance to the perimeter of the Fire/Explosion/Toxic area is measured to indicate the approximate size of the area. This allows for a comparison between the different bunkering scenarios.

Bunkering scenarios

Bunkering scenarios are based on the outcomes of RH2INE Sub-study 1a, SuAc 1.1b

Scenario	Description
1a	Swapping containers with pressurized hydrogen (300 bar) at container terminals (start-up case) – no storage in stack
1b	Swapping containers with pressurized hydrogen (500 bar) at container terminals (future case) – storage in stack
2a	Truck-to-ship bunkering of gaseous hydrogen via hose to fixed tanks on board (start-up case) (500 bar)
2b	Bunker station to ship, bunkering of gaseous hydrogen via hose to fixed tanks on board (future case) (380 bar)
3	Truck-to-ship bunkering of liquid hydrogen
4a	Truck-to-ship bunkering of refrigerated liquid ammonia
4b	Truck-to-ship bunkering of pressurized liquid ammonia
5	Truck-to-ship bunkering of methanol

Parameters and assumptions for QRA

Scenario	Description	H_2 transfer frequency	Unit	Transfer rate	Unit
1a	Swapping 44 m^3 containers with pressurized hydrogen (300 bar) at container terminals (start-up case) – no storage in stack	156	Container swaps per year	-	-
1b	Swapping 44 m^3 containers with pressurized hydrogen (500 bar) at container terminals (future case) – storage in stack	730	Container swaps per year	-	-
2a	Truck-to-ship bunkering of gaseous hydrogen via hose to fixed tanks on board (start-up case)	2327	Bunker hours per year	60	g/s
2b	Bunker station to ship, bunkering of gaseous hydrogen via hose to fixed tanks on board (future case)	800	Bunker hours per year	3000	kg/h
3	Truck-to-ship bunkering of liquid hydrogen	562	Bunker hours per year	65	m^3/h
4a	Truck-to-ship bunkering of refrigerated liquid ammonia	422	Bunker hours per year	65	m^3/h
4b	Truck-to-ship bunkering of pressurized liquid ammonia	376	Bunker hours per year	65	m^3/h
5	Truck-to-ship bunkering of methanol	306	Bunker hours per year	65	m^3/h

Results for external safety distances & risk calculations

Results for external safety distances

Scenario	Description	External safety distance* [m]
1a	Swapping 44 m^3 containers with pressurized hydrogen (300 bar) at container terminals (start-up case) – no storage in stack	39
1b	Swapping 44 m^3 containers with pressurized hydrogen (500 bar) at container terminals (future case) – storage in stack	129
2a	Truck-to-ship bunkering of gaseous hydrogen via hose to fixed tanks on board (start-up case)	37
2b	Bunker station to ship, bunkering of gaseous hydrogen via hose to fixed tanks on board (future case)	106
3	Truck-to-ship bunkering of liquid hydrogen	82
4a	Truck-to-ship bunkering of refrigerated liquid ammonia	175
4b	Truck-to-ship bunkering of pressurized liquid ammonia	543
5	Truck-to-ship bunkering of methanol	79

*Measured from the receiving vessel's bunker manifold to the 10^{-6}/year contour. For swapping containers, from the location of the containers on the vessel land inwards.

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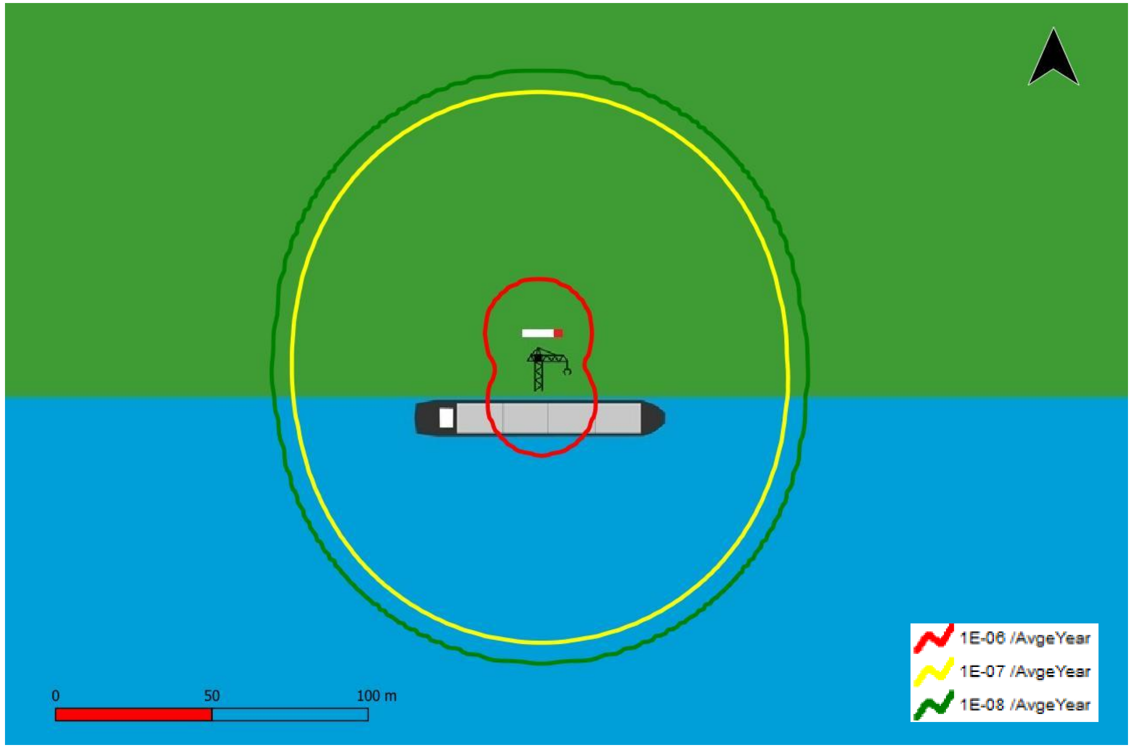
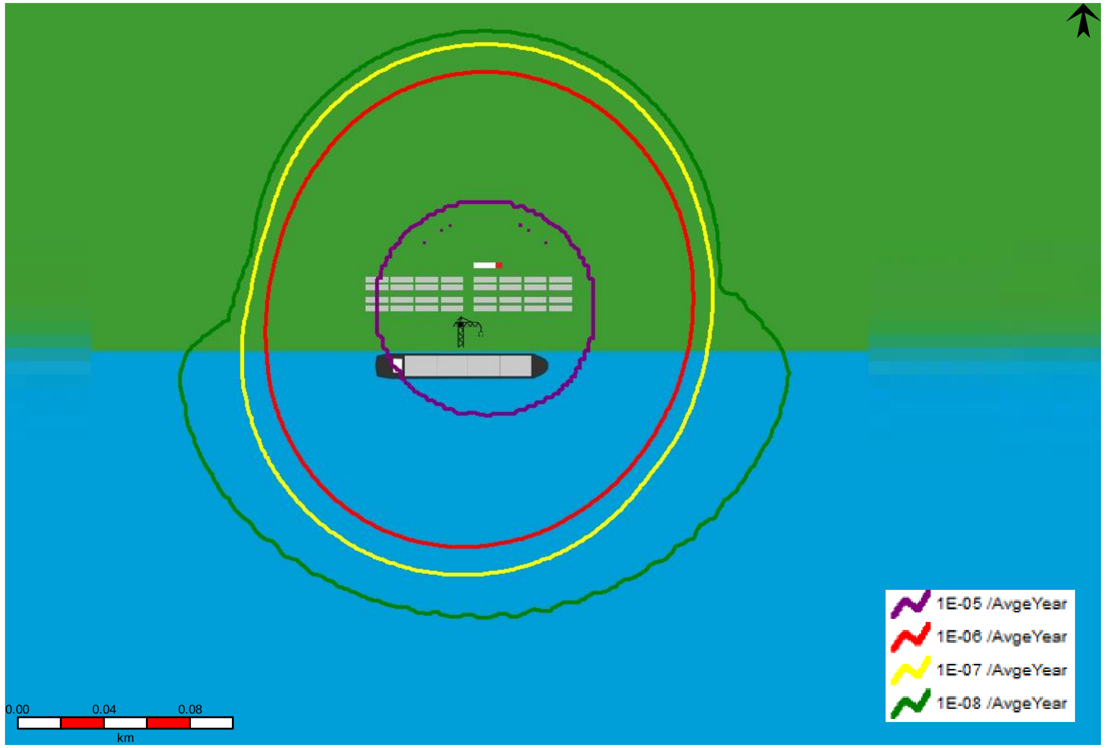
Results of risk calculations (1/5)

Scenario 1a: Swapping containers with pressurized hydrogen (300 bar) at container terminals (start-up case) – no storage in stack



External safety distance: 39 m

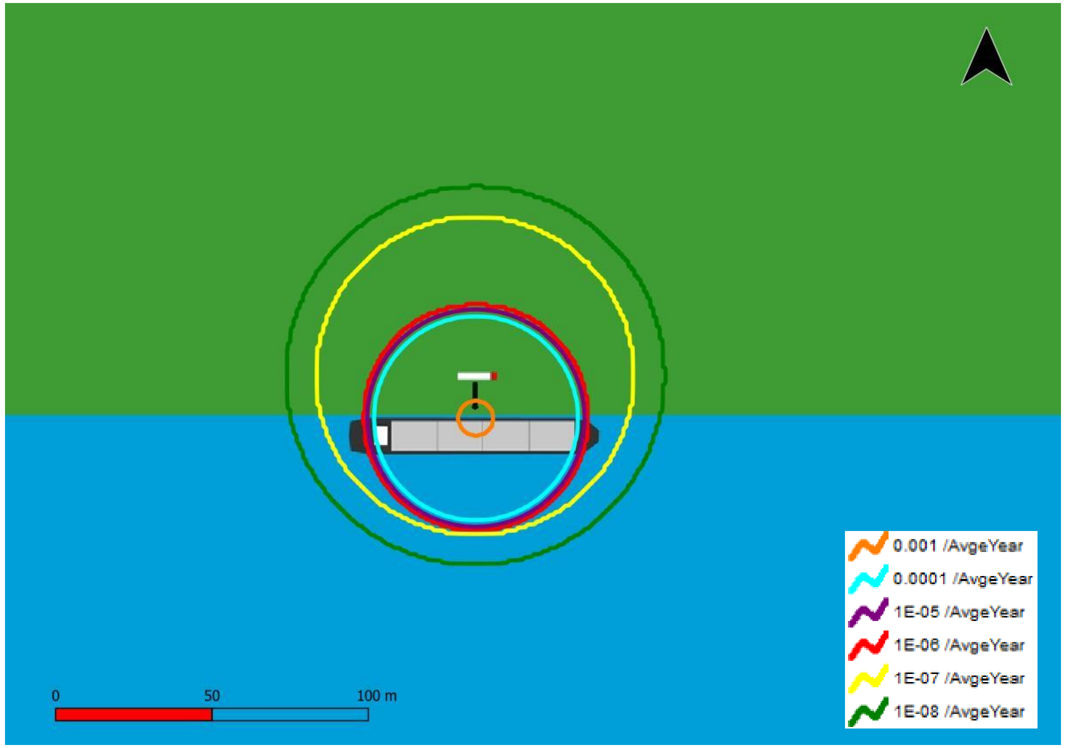
Scenario 1b: Swapping containers with pressurized hydrogen (500 bar) at container terminals (future case) – storage in stack



External safety distance: 129 m

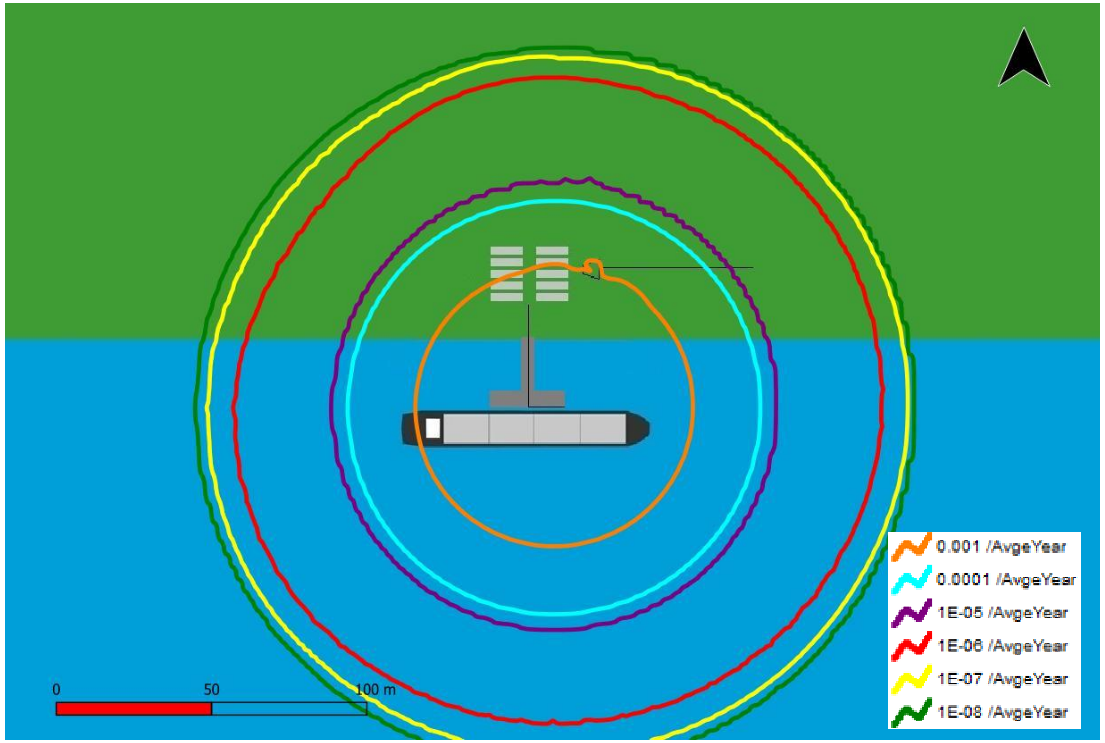
Results of risk calculations (2/5)

Scenario 2a: Truck-to-ship bunkering of gaseous hydrogen via hose to fixed tanks on board (start-up case)



External safety distance: 37 m

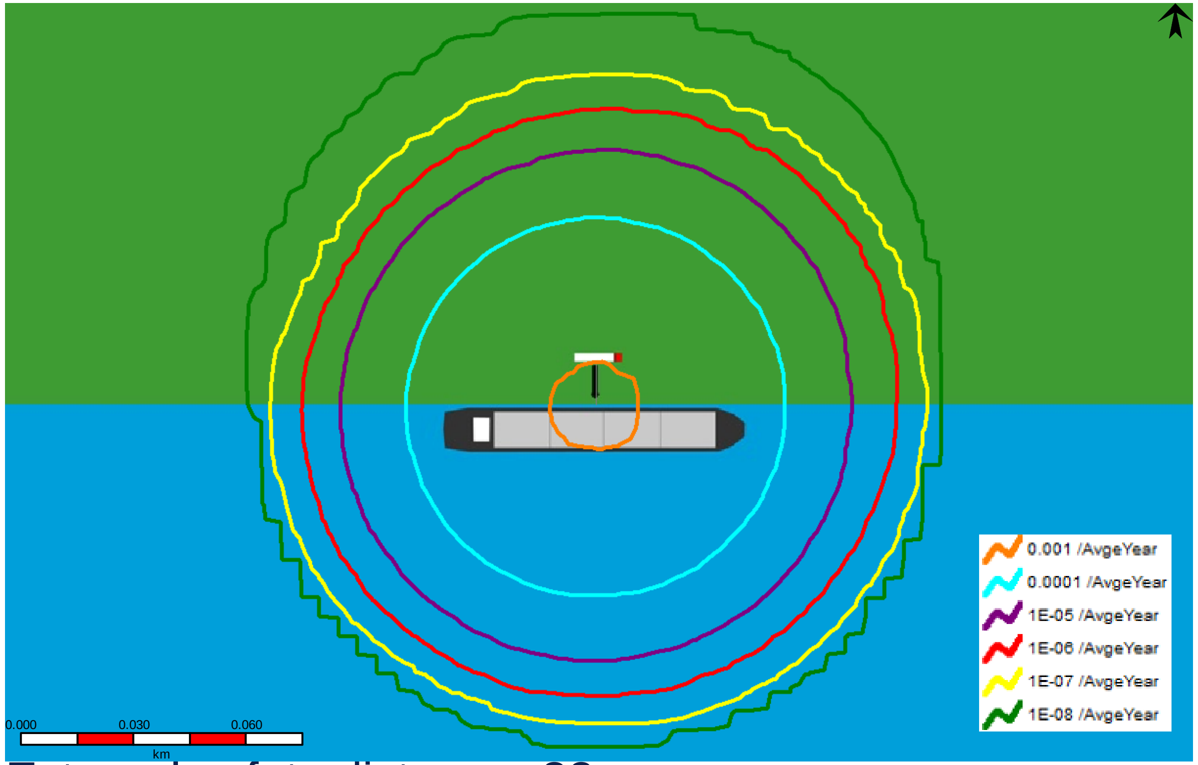
Scenario 2b: Bunker station to ship, bunkering of gaseous hydrogen via hose to fixed tanks on board (future case)



External safety distance: 106 m

Results of risk calculations (3/5)

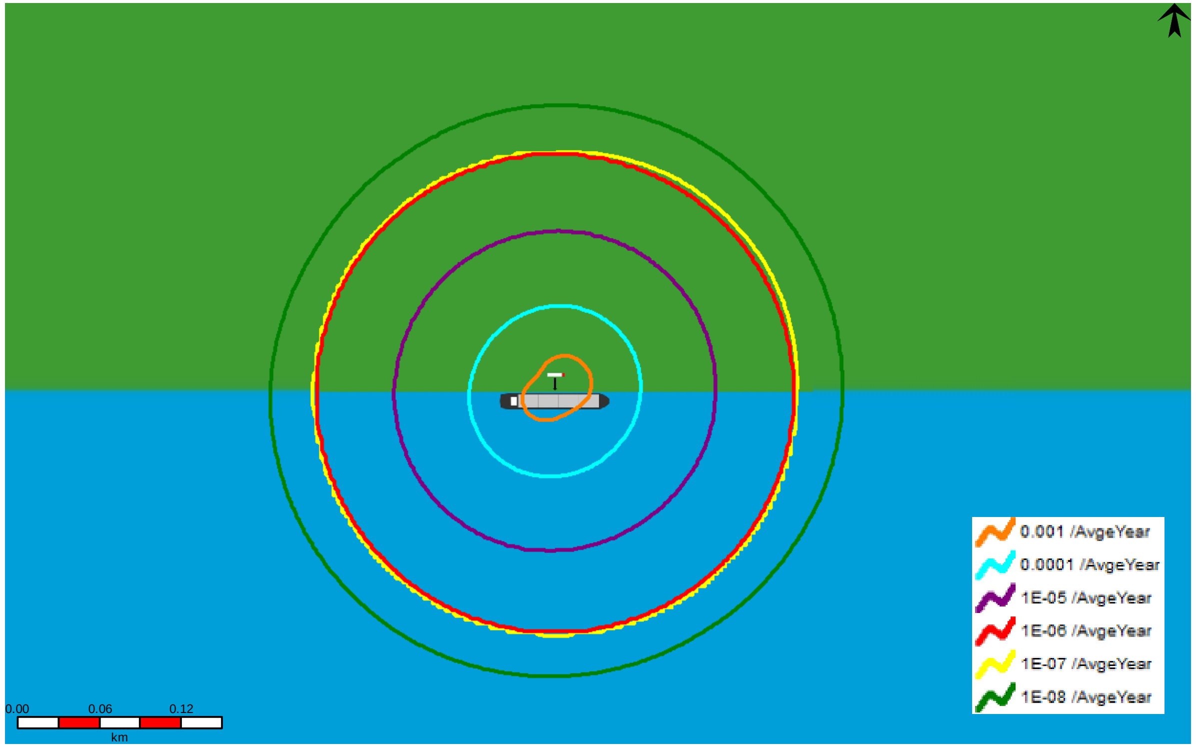
Scenario 3: Truck-to-ship bunkering of liquid hydrogen



External safety distance: 82 m

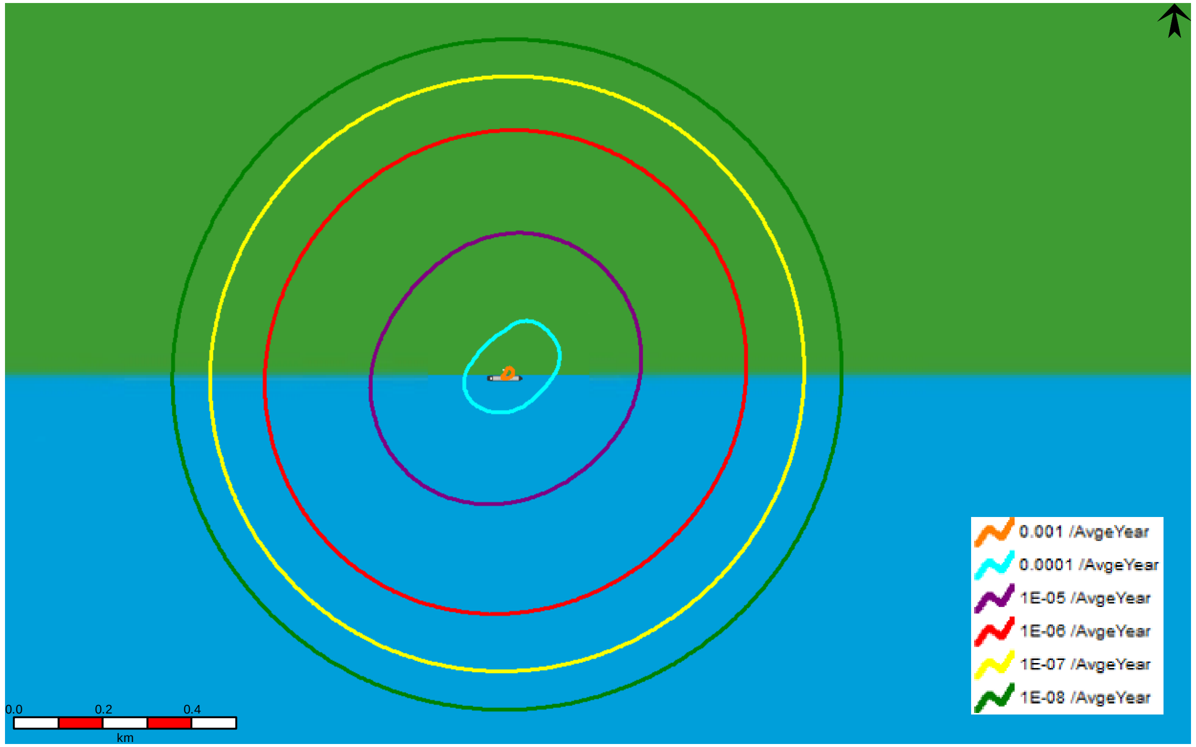
Results of risk calculations (4/5)

Scenario 4a: Truck-to-ship bunkering of refrigerated liquid ammonia



External safety distance: 175 m

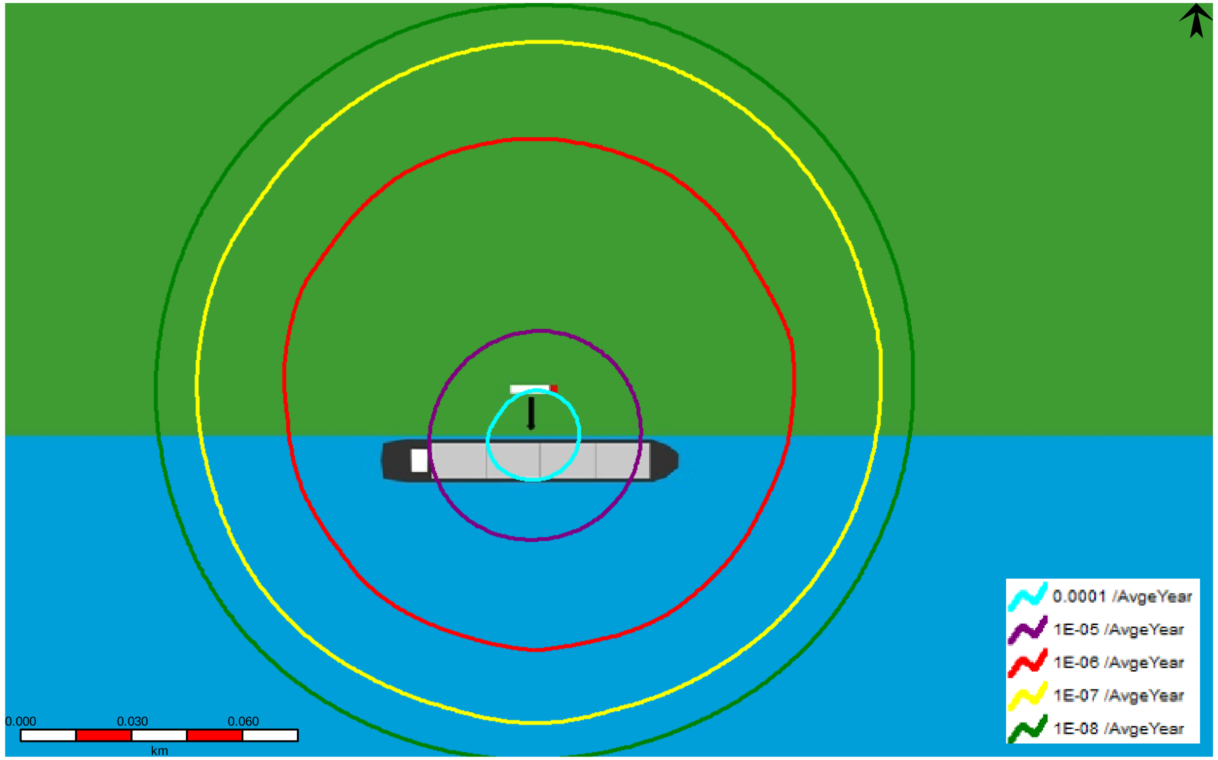
Scenario 4b: Truck-to-ship bunkering of pressurized liquid ammonia



External safety distance: 543 m

Results of risk calculations (5/5)

Scenario 5: Truck-to-ship bunkering of methanol



External safety distance: 79 m

Conclusions – external safety distances (1/2)

- The external safety distances for swapping H2 containers at container terminals are relatively small (39 m) when containers are directly loaded from trailer onto the receiving vessel.
- However, in the future case when demand grows and storage of containers in the stack might be needed (to create a buffer stock), the external safety distance could increase with about a factor 3. This should normally not be a problem for container terminals because of their layout and location, which provides sufficient stand-off distance to vulnerable objects.
- Bunkering of gaseous hydrogen via hose results in relatively small distances (approx. 40 m) when bunkering takes place directly from a (tube)-trailer. The distance for bunker stations could go up to approximately 100 m.
- For truck-to-ship (TTS) bunkering of liquid hydrogen and methanol result in safety distances of approximately 80 m, which are in line with previously calculated distances for TTS bunkering of LNG. In comparison, the external safety distance for TTS LNG bunkering to inland vessels was calculated at 70 m in the LNG Masterplan study of 2015 (Source: http://www.lngmasterplan.eu/, D 2.4.2. Part C).

Conclusions – external safety distances (2/2)

- For bunkering ammonia, the safety distances are very large and go up to 543 m, which are caused by the toxic consequences. The distances for pressurized ammonia are about a factor 3 larger than for bunkering refrigerated ammonia.
- It will be challenging to introduce ammonia as a fuel in IWT due to the large safety distances for bunkering ammonia with a hose.
- This could be showstopper for bunkering ammonia in inland ports and waterways where residential areas and industries etc. could be nearby.

Results for focus areas

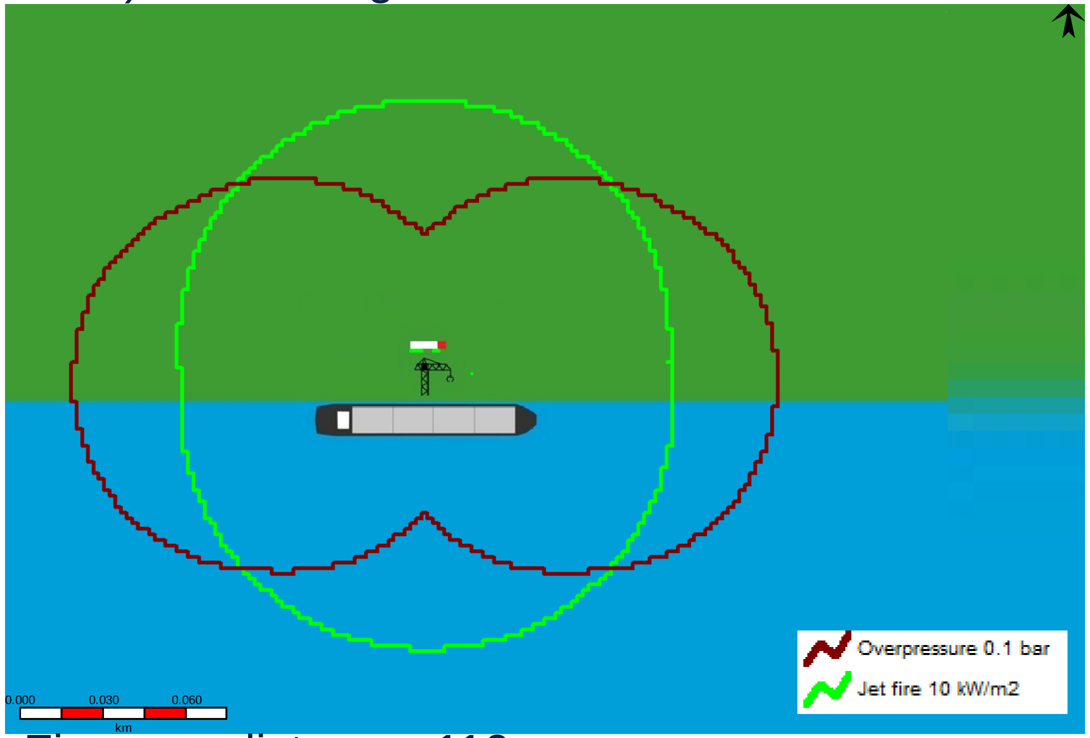
Results for focus areas

Scenario	Description	Fire area distance* [m]	Explosion area distance* [m]	Toxic area distance* [m]
1a	Swapping 44 m^3 containers with pressurized hydrogen (300 bar) at container terminals (start-up case) – no storage in stack	110	128	-
1b	Swapping 44 m^3 containers with pressurized hydrogen (500 bar) at container terminals (future case) – storage in stack	150	223	-
2a	Truck-to-ship bunkering of gaseous hydrogen via hose to fixed tanks on board (start-up case)	60	132	-
2b	Bunker station to ship, bunkering of gaseous hydrogen via hose to fixed tanks on board (future case)	105	195	-
3	Truck-to-ship bunkering of liquid hydrogen	150	185	-
4a	Truck-to-ship bunkering of refrigerated liquid ammonia	-	-	777
4b	Truck-to-ship bunkering of pressurized liquid ammonia	-	-	1203
5	Truck-to-ship bunkering of methanol	122	-	-

*Measured from the receiving vessel's bunker manifold to the boundary of the contour. For swapping containers, from the location of the containers on the vessel land inwards.

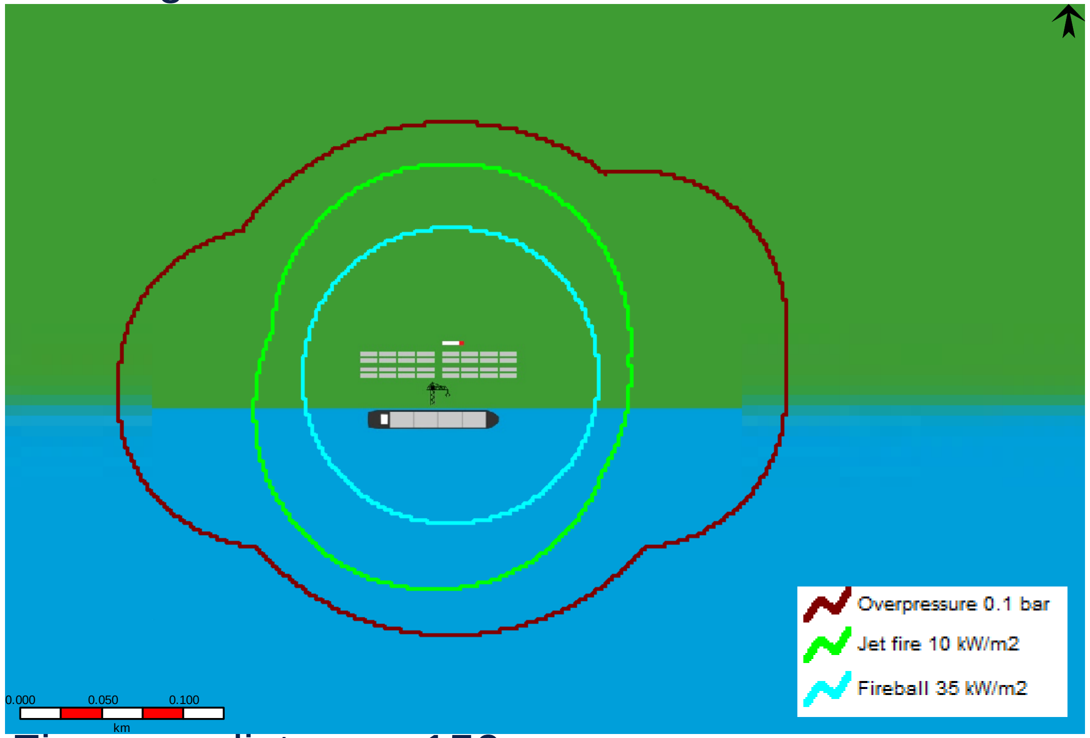
Focus areas (1/5)

Scenario 1a: Swapping containers with pressurized hydrogen (300 bar) at container terminals (start-up case) – no storage in stack



Fire area distance: 110 m
Explosion area distance: 128 m

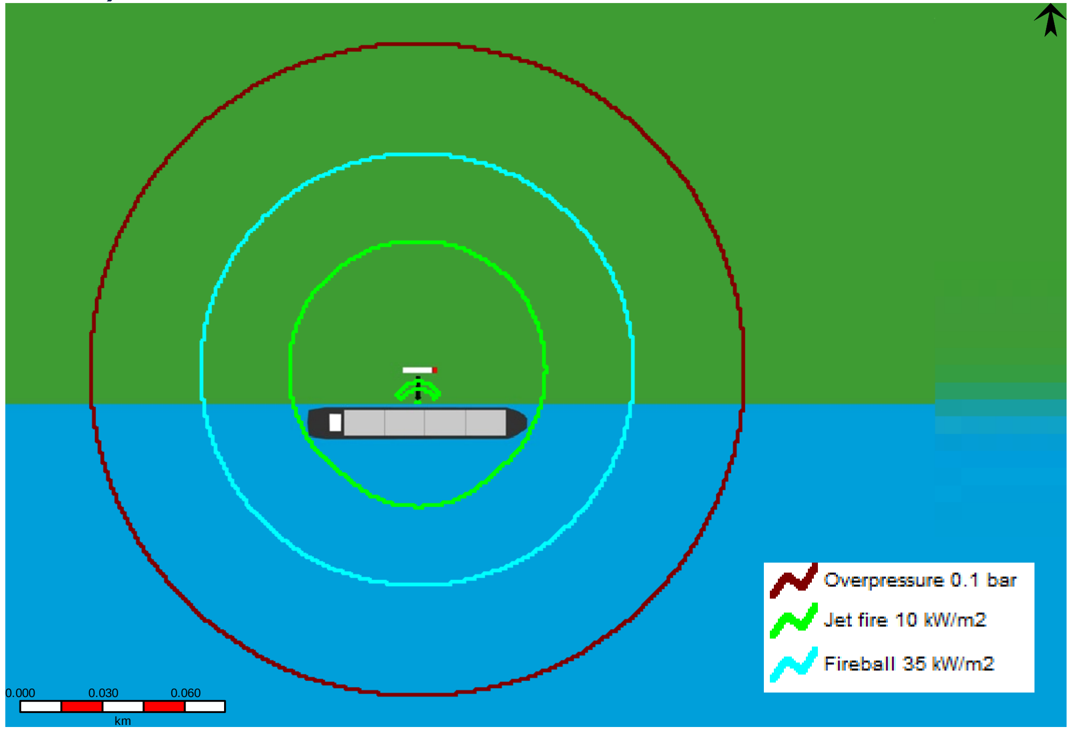
Scenario 1b: Swapping containers with pressurized hydrogen (500 bar) at container terminals (future case) – storage in stack



Fire area distance: 150 m
Explosion area distance: 223 m

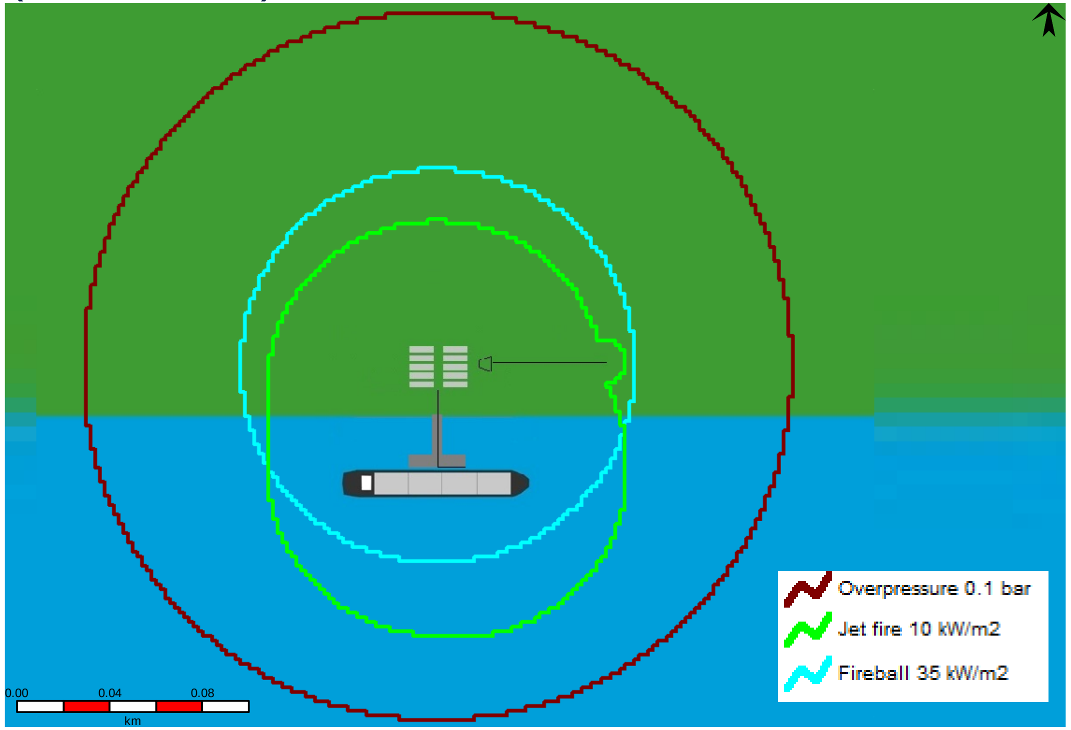
Focus areas (2/5)

Scenario 2a: Truck-to-ship bunkering of gaseous hydrogen via hose to fixed tanks on board (start-up case)



Fire area distance: 60 m
Explosion area distance: 132 m

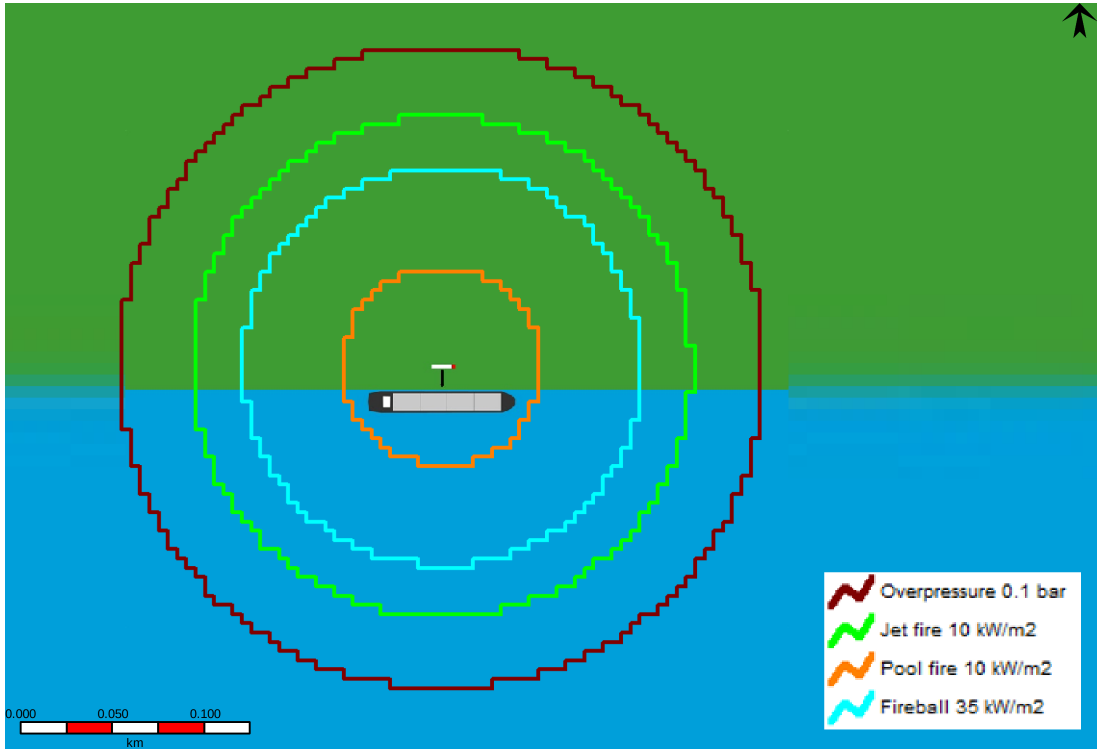
Scenario 2b: Bunker station to ship, bunkering of gaseous hydrogen via hose to fixed tanks on board (future case)



Fire area distance: 105 m
Explosion area distance: 195 m

Focus areas (3/5)

Scenario 3: Truck-to-ship bunkering of liquid hydrogen



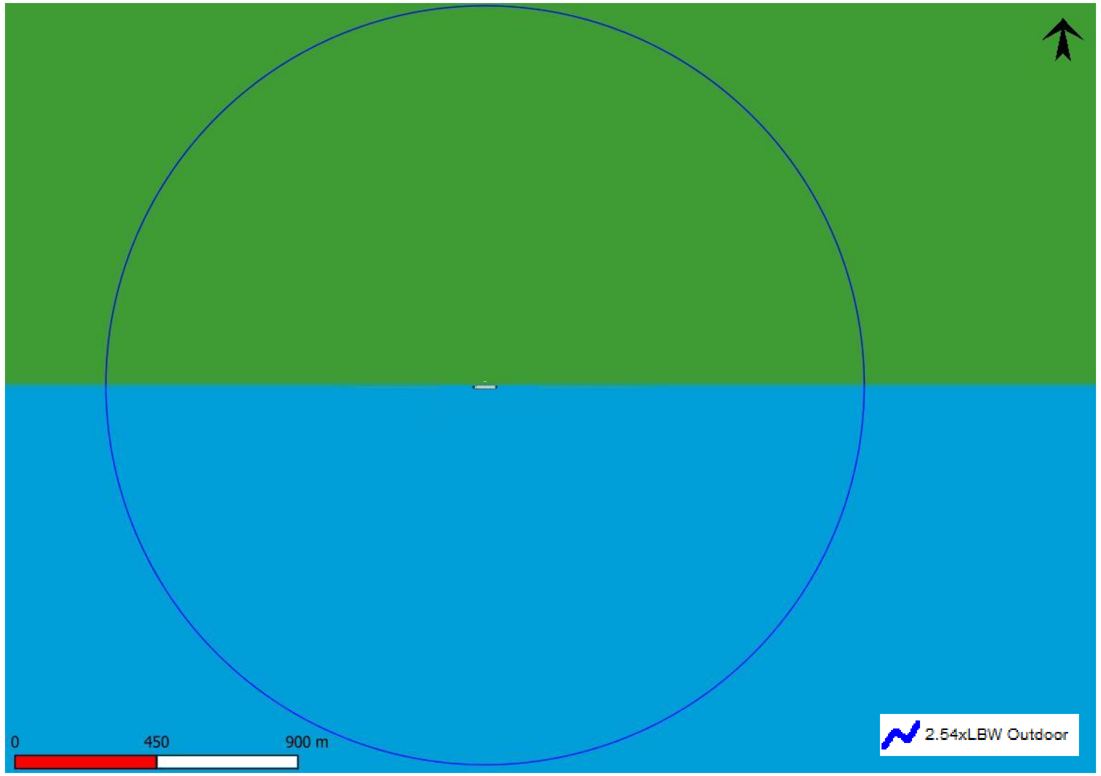
Fire area distance: 150 m
Explosion area distance: 185 m

Focus areas (4/5)

Scenario 4a: Truck-to-ship bunkering of refrigerated liquid ammonia

Toxic area distance: 777 m

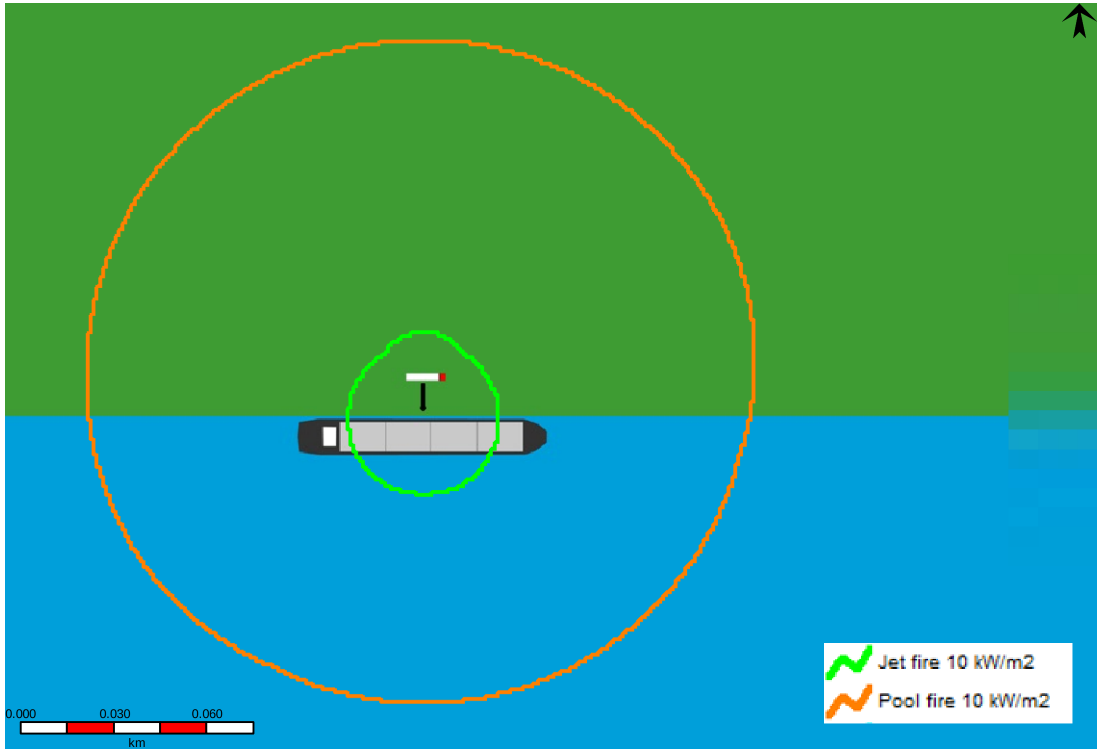
Scenario 4b: Truck-to-ship bunkering of pressurized liquid ammonia



Toxic area distance: 1203 m

Focus areas (5/5)

Scenario 5: Truck-to-ship bunkering of methanol



Fire area distance: 122 m

Conclusions – focus areas

- The explosion focus areas are all in the range of approximately 130 m – 220 m for bunkering hydrogen in gaseous (via hose or container swapping) or liquid form.
- The fire focus areas are between 60 m – 150 m.
- The focus areas for bunkering ammonia are very large (in the range of 1 km) due to the toxic impact.
- Within the areas, specific construction requirements may be enforced for buildings to offer protection against fire, explosion or toxic impact to the occupants inside.

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