Ammonia

As an energycarrier

Antea Group

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20 October 2021

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About us

Antea Group is an international engineering and consultancy firm. We combine valuable knowledge with a pragmatic approach, to come up with workable solutions. This makes us a multifaceted, independent partner for companies and government bodies

Just as we have been for over 65 years now

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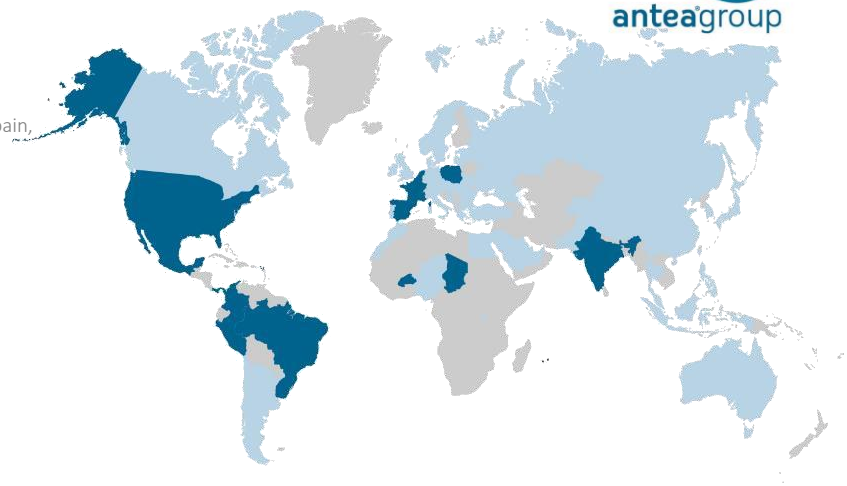
WORLDWIDE

Offices in:
The Netherlands, France, USA, Belgium, Spain, Poland, India and Brazil

More than 90 offices



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Shifts due to the energy transition

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- How energy is created
  - Renewable sources, less centralized
- How we transport energy
  - Power grids aren't designed for this
  - Peak generation vs dips
- Which fuels we use
  - Preferably carbon emission free
- How we store energy
  - Batteries
  - Storage of peak energy
- Where we store energy
  - Centralised in tanks / coal fields
  - Near users

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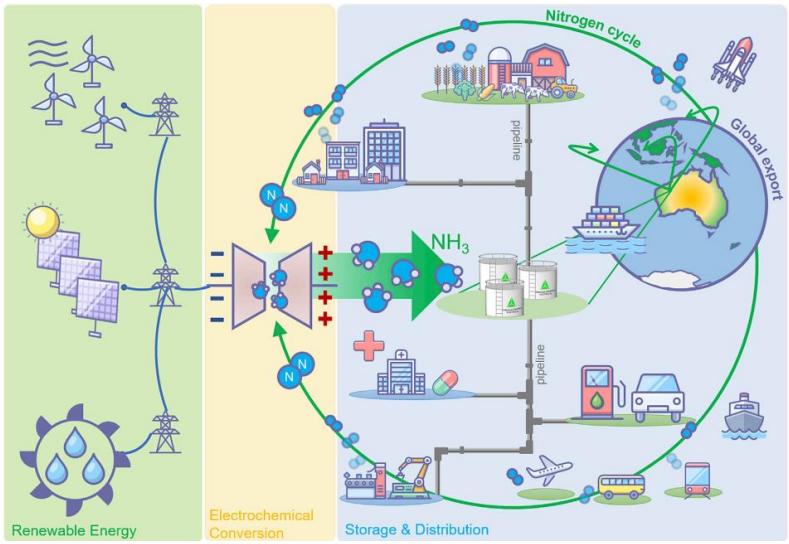
Ammonia as an Hydrogen carrier

- Renewable energy
- Electrochemical conversion
- Intermediate storage
  - Distribution (global)
  - Peak storage
  - Direct delivery to end-users



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Use of ammonia

- Fertiliser (production)
- As a coolant
- Base chemical
- Use in renewable energy (hydrogen carrier)
- As a (marine) fuel
- As a co-fuel in powerplants

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Ammonia as an Hydrogen carrier

- Storage of energy (e.g. seasonal flux and/or transportation)
  - Hydrogen
    - High pressure (700 barg), or
    - Low temperature (-253 C)
  - Ammonia
    - Temperature (-33 C), or
    - Pressure (~6,5 barg)
  - High volumetric energy density
  - Experience with long storage and transportation

Fuel	H_2 content (wt%)	Volumetric energy density (Wh/L)
Ammonia	17.7	4325
Methanol	12.5	4600
Ethanol	13	6100
Gasoline	15.8	9700
Hydrogen	100	1305

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Ammonia as an Hydrogen carrier

- Drawbacks are apparent
  - Ammonia is not without safety risks
    - Toxicity and aqua toxic
    - Public perception is key
  - Energy loss when creating ammonia
    - Estimated at 20% energy loss
  - Emission of ammonia during transport
    - Dependant on design conditions

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Ammonia risks

- Inhalation
  - Ammonia is irritating and corrosive. Exposure to high concentrations of ammonia in air causes immediate burning of the nose, throat and respiratory tract.
- Skin/Eye contact:
  - Corrosive gas which can cause severe irritation and burn marks. Which can lead to severe injury.
- Aquatoxic
  - Creates a toxic buildup in aquatic organisms.
- Vapour is flammable
  - When exposed to a liquid pool fire: risk of BLEVE

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Ammonia characteristics

Property	Hydrogen	Ammonia	Methane	Propane
Molar mass	2.016	17	16	44,1 g/mol
Density	70	681	423	600 kg/m^3 (1 bar at bp)
Boilingpoint	-253	-33	-162	-42 C
Flash point	<-253	11	-188	-104 C
Auto ignition temperature	500-571	651	537	470 C
LFL	4	15	4,4	2,4 %
UFL	75	25	17	9,5 %
Minimum ignition energy in air	0,019	680	0,29	0,25 mJ
Maximum laminar burning velocity	2,91	0,07	0,37	0,43 m/s
Caloric value	120	18,6	50	46,4 MJ/kg

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Be aware of the typical risks

- Low storage temperature,
  - cause of brittle failure
  - Frost heave
- Creation of over- or underpressure
- Roll-over of fluids during tank filling
- Stress corrosion cracking (of metal welds)
- Corrosion under isolation
- Releases can cause toxic clouds
  - Indoor releases can easily build up to dangerous levels

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Safety first during design

Safe by design philosofy

- Minimization
- Substitution
- Moderation
- Simplification
- Improving fault tolerances
- Limitation of dangerous effects
- Incorporation of fool-proof principles

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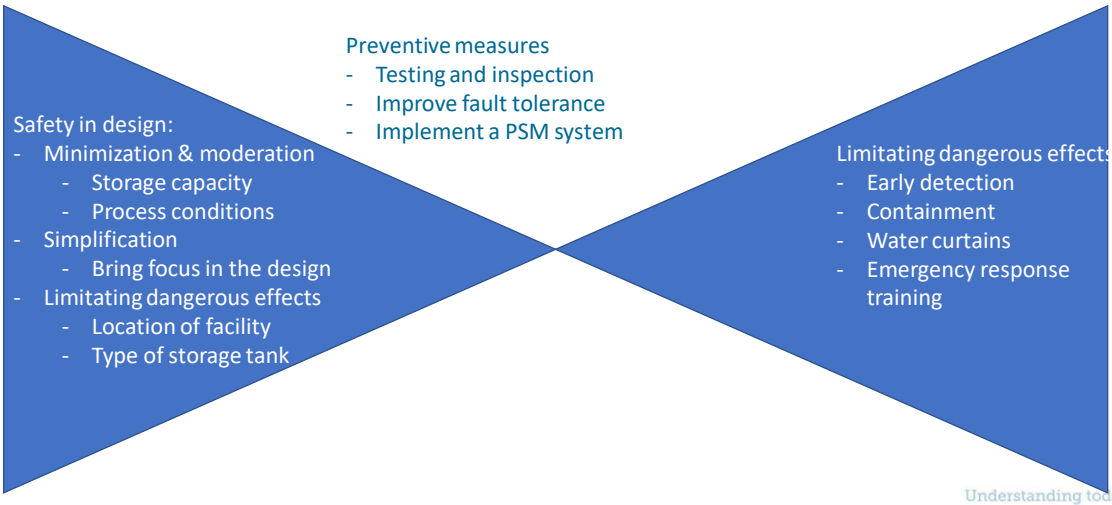
Safety first during design



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Dealing with safety risks of NH_3

1. (Quantitative) risk analyses:
   a) industrial site
   b) transportation
   c) reduce or mitigate the probability of an incident

2. To reduce the effects of an incident:
   a) look at the environment
   b) reduce the ammonia pool
   c) reduce the dispersion of the ammonia cloud

3. Safety management:
   a) best available techniques
   b) control and manage safety measures

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Dutch situation

- Reduction of ammonia transport
- Safety deals to move ammonia plants
- Public perception:
  - Toxic bombs

- The Dutch 'Nitrogen-crisis'
  - Oversaturation of Natura 2000 nature

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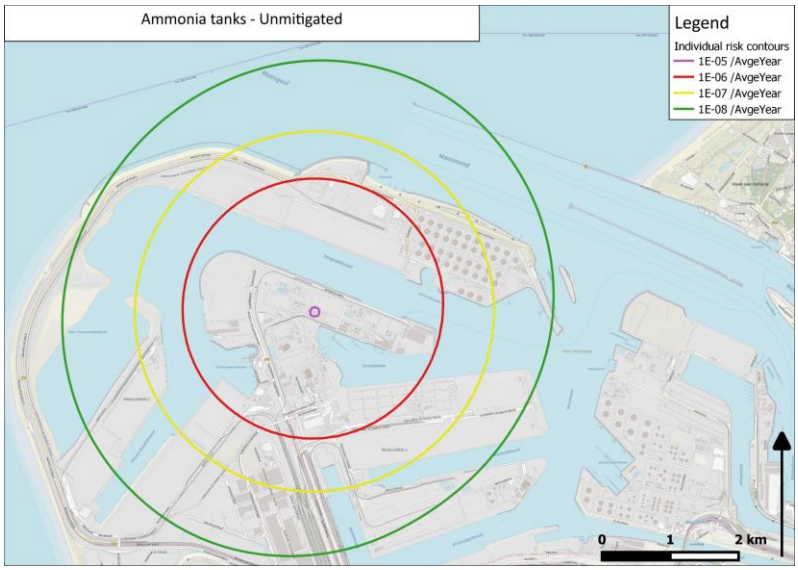
Quantitative risk analyses



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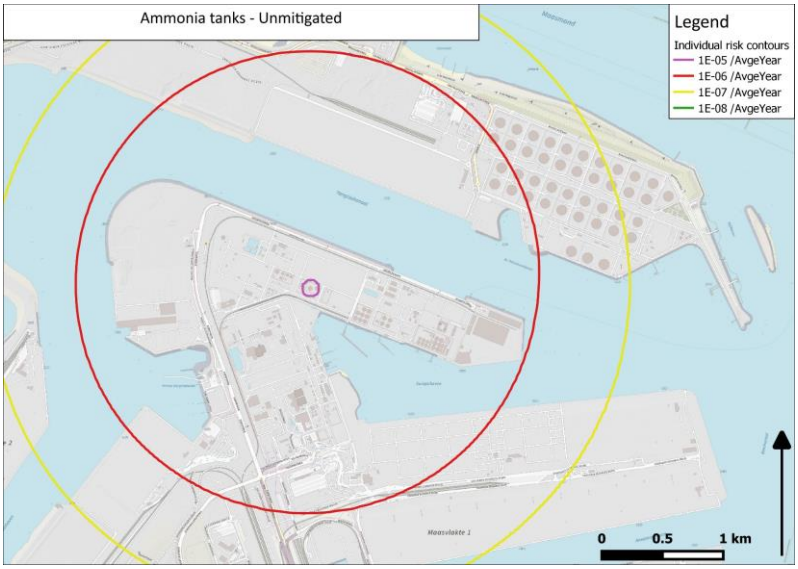
Quantitative risk analyses



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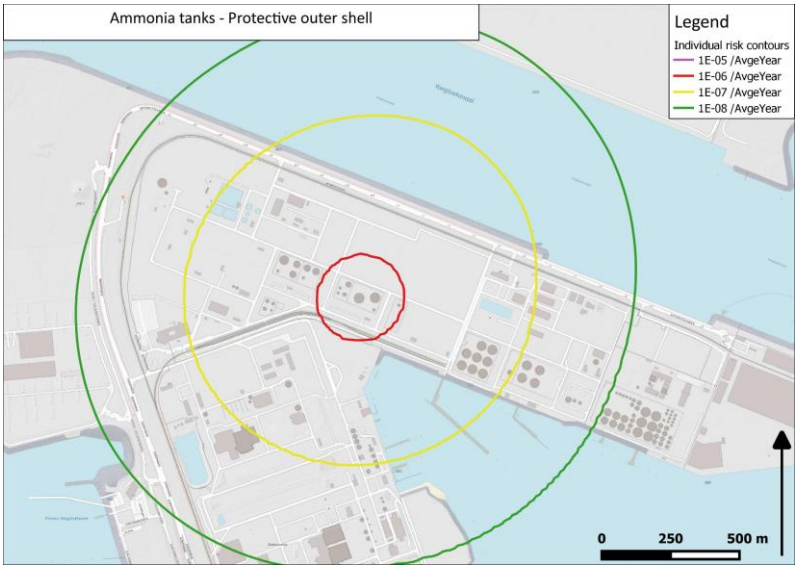
Quantitative risk analyses



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Quantitative risk analyses

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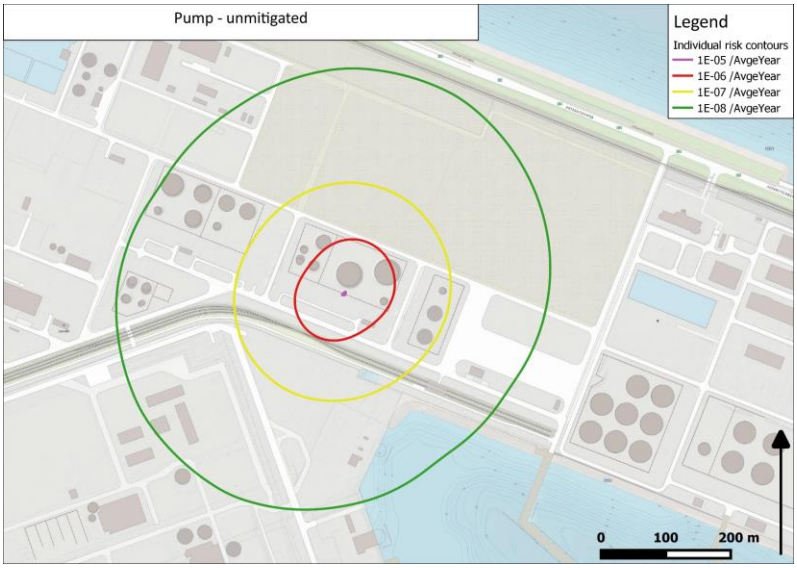
Quantitative risk analyses



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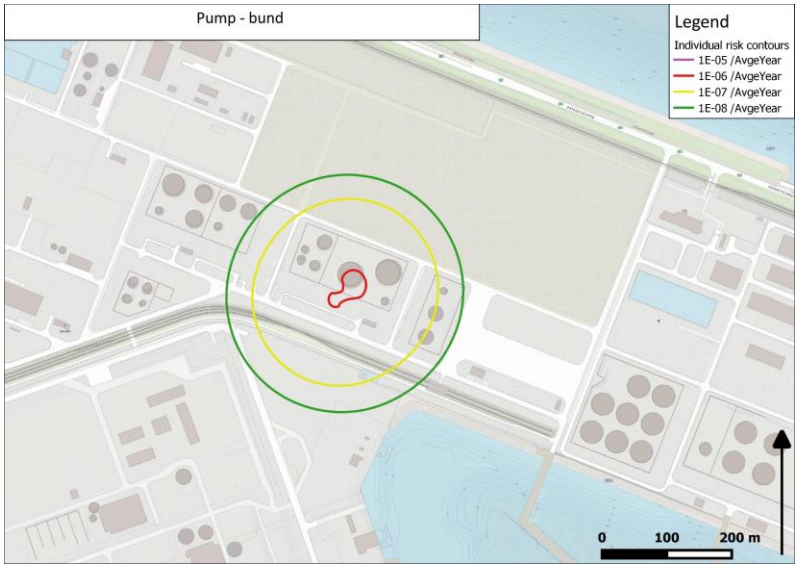
Quantitative risk analyses



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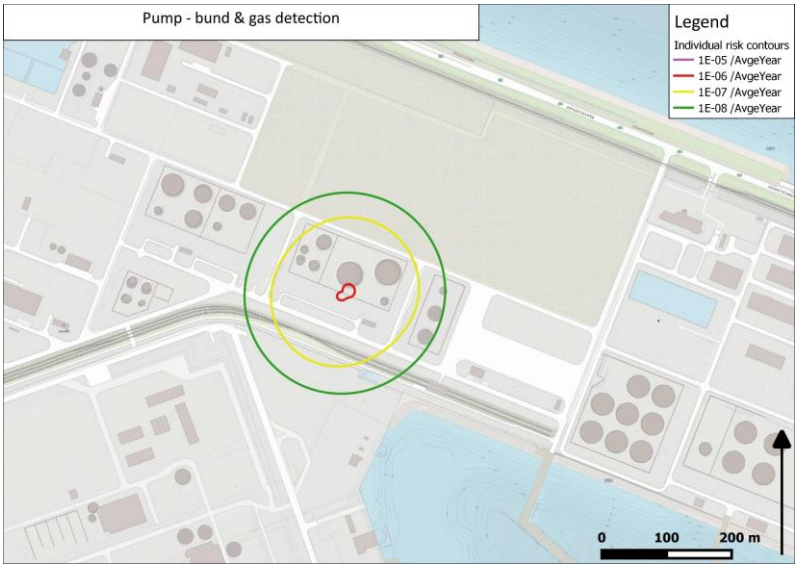
Quantitative risk analyses



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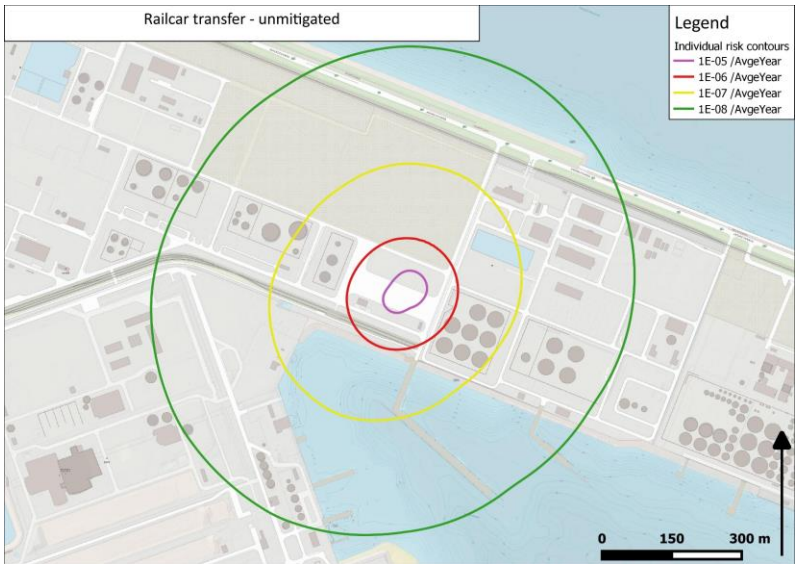
Quantitative risk analyses



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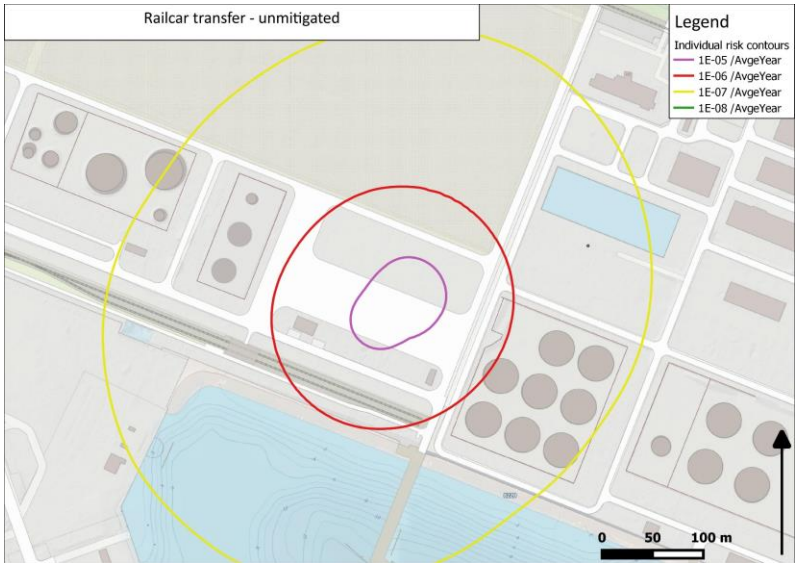
Quantitative risk analyses



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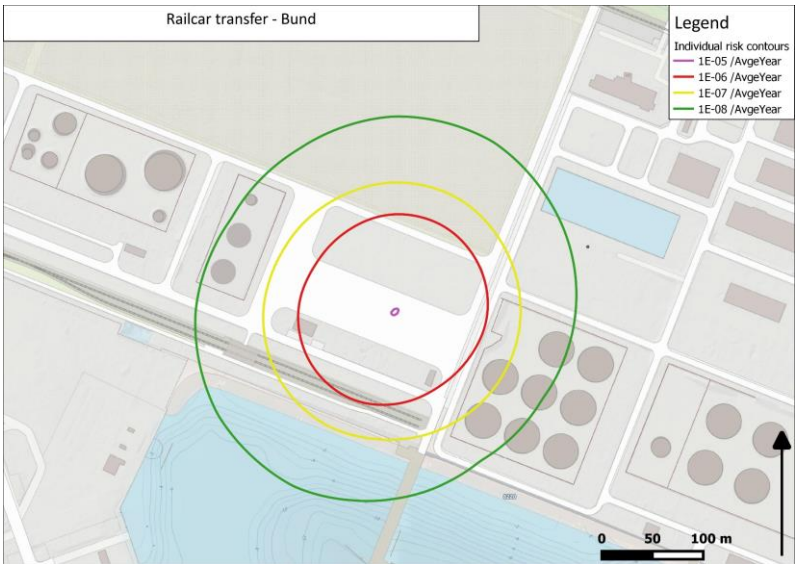
Quantitative risk analyses



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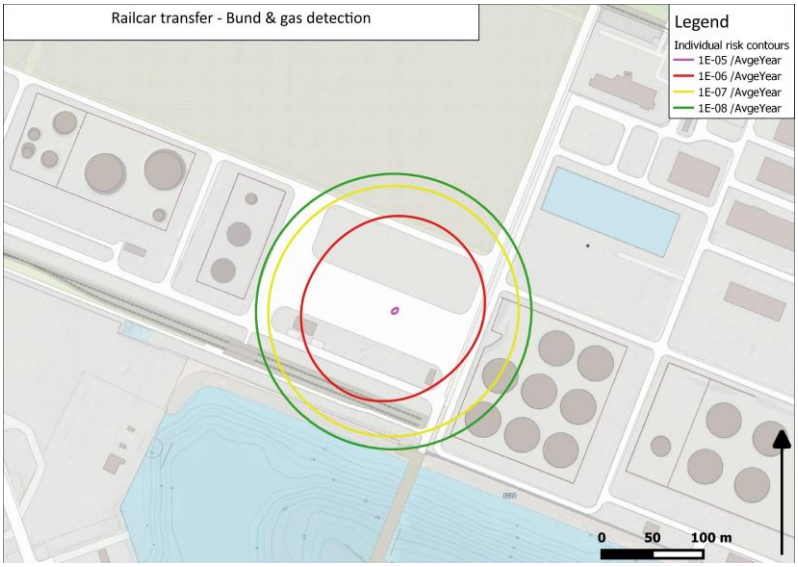
Quantitative risk analyses



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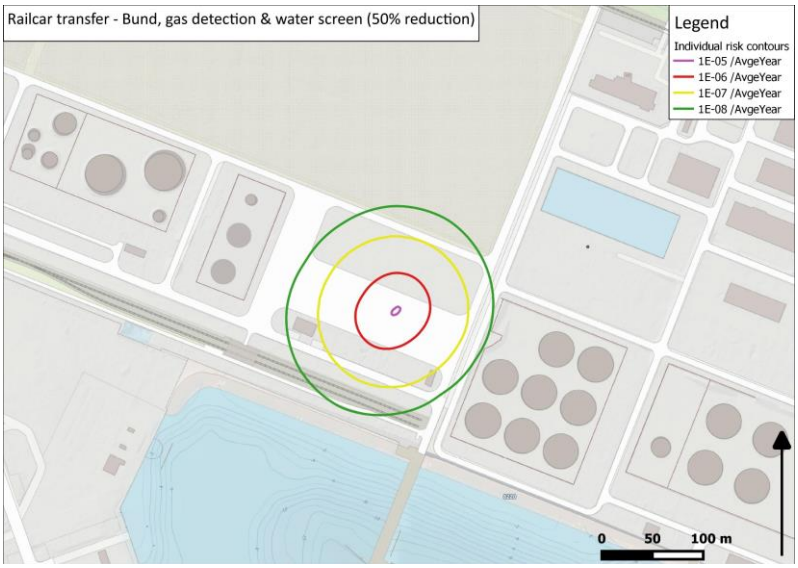
Quantitative risk analyses



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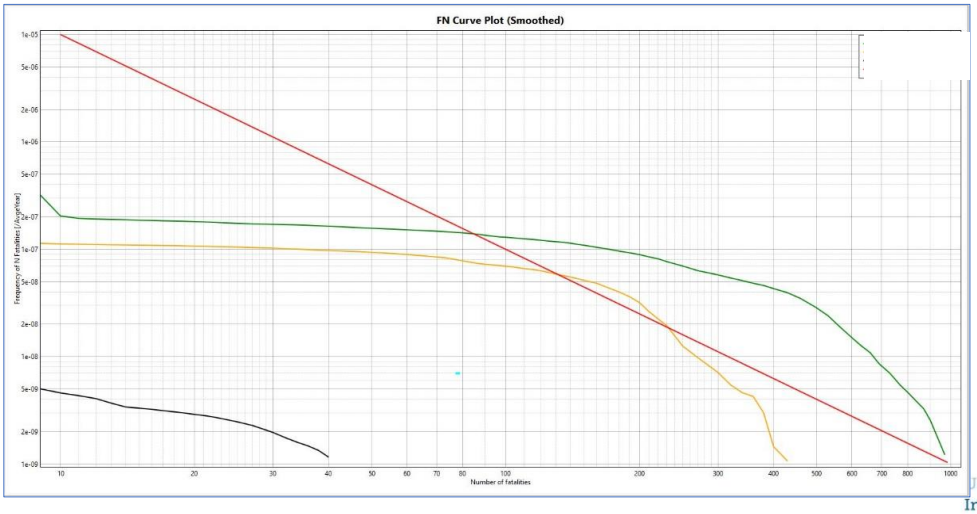
Quantitative risk analysis: societal risk



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How to improve your image

- Show why ammonia is beneficial for society
  - Energy transition
- Be safe in what you do
  - Control and manage safety measures
  - Minimize the risks in design
  - Testing and inspecting, and keep up a good administration
  - Safety management
  - Safety culture in your company: starts with good and responsible leadership
- Explain what you do
  - Good relationship with authorities:
    be sure you follow up safety legislation and permit rules
  - Good relationship with your neighbours:
    take complaints seriously, be open in what you do

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Summary

Managing Risks and image of ammonia:

- Don’t be afraid, but be aware of the risks
- Implement, manage and control safety measures applicable for your specific situation
- Safety culture = good leadership = be an example for your employees
- Manage your image: don’t ignore feelings of unsafety or other complaints in the surroundings of your business, but: inform, discuss, open up!

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Questions

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