# BowTie Analysis for the hazard "Storage of H<sub>2</sub> in a Salt Cavern"

In this Annex A.2 the BowTies are detailed for the measures that can be taken to reduce risks and mitigate consequences, including monitoring

## **Categories of measures:**

- Prevention measure (green colour)
  - Design (including material selection, operational management)
  - Testing
- Monitoring measure (yellow colour)
  - Monitoring
  - Logging
- Recovery measure (orange colour)



# T1: Leakage of H<sub>2</sub> in the subsurface

Detailed BowTies include:

T1-W: <u>Top Event 1</u>, <u>W</u>ell T1-O: <u>Top Event 1</u>, <u>Overburden</u> T1-C: <u>Top Event 1</u>, <u>Cavern</u>

T1-X: Top Event <u>1</u>, <u>X</u>Consequences





#### Detailed BowTie – Subsurface Leakage Overburden Threats – T1-O





# Detailed BowTie – Subsurface Leakage Cavern Threats – T1-C quantification of risk caverns"

Annex A.2 to TNO report 2021 R10526 "Identification and quantification of risks of subsurface hydrogen storage in salt caverns"





#### Detailed BowTie – Subsurface Leakage Consequences – T1-X





# T2: Leakage of H<sub>2</sub> at the surface

Detailed BowTies include:

T2-W: <u>T</u>op Event <u>2</u>, <u>W</u>ell

T2-X: <u>Top Event 2</u>, <u>X</u>Consequences



### Detailed BowTie – Surface Leakage Well Threats – T2-W

Annex A.2 to TNO report 2021 R10526 "Identification and quantification of risks of subsurface hydrogen storage in salt caverns"



Adverse effects to humans and animals due to air pollution with H<sub>2</sub> Minimize Minimize Warn local Determine Execute emergency Install/use leakage cause of leakage stakeholders volume and flow presence of response plan detection and H<sub>2</sub>-gas humans & animals rate during (evacuation etc) and authorities and repair presence monitoring in vicinity of site release equipment at surface Hazard **Extreme noise levels** Storage of H<sub>2</sub> leading to hearing in a salt Minimize Use proper Execute emergency Determine cause of Warn local damage presence of **Personal Protective** leakage and repair response plan stakeholders and cavern humans & animals Equipment (difficult due to noise) (evacuation etc) authorities in vicinity of site Shockwave from explosion causing structural damage, injury Prevent Stimulate immediate Install/use leakage Execute emergency Top event or death accumulation of a ignition on release response plan detection and H<sub>2</sub>-gas high-concentration to prevent explosion (evacuation etc) presence monitoring Leakage of H<sub>2</sub> H<sub>2</sub> cloud equipment at surface at the surface Heat radiating from flash fire or jet flame causing structural damage, injury Install/use leakage Execute fire Execute emergency Warn local Determine cause of or death detection and H<sub>2</sub>-gas leakage and repair prevention plan response plan stakeholders and presence monitoring (evacuation etc) authorities equipment at surface Injury or death - occurs in combination with Perform a QRA other consequences (fire, Reconsider Minimize Warn local Record incidents and Execute emergency (quantify physical explosion) ATEX zonation presence of stakeholders and follow-up with response plan effects, assess failure (debrining risk) humans & animals authorities (evacuation etc) additional measures frequencies) in vicinity of site

### Detailed BowTie – Surface Leakage Consequences – T1-X

Annex A.2 to TNO report 2021 R10526 "Identification and quantification of risks of subsurface hydrogen storage in salt caverns"

