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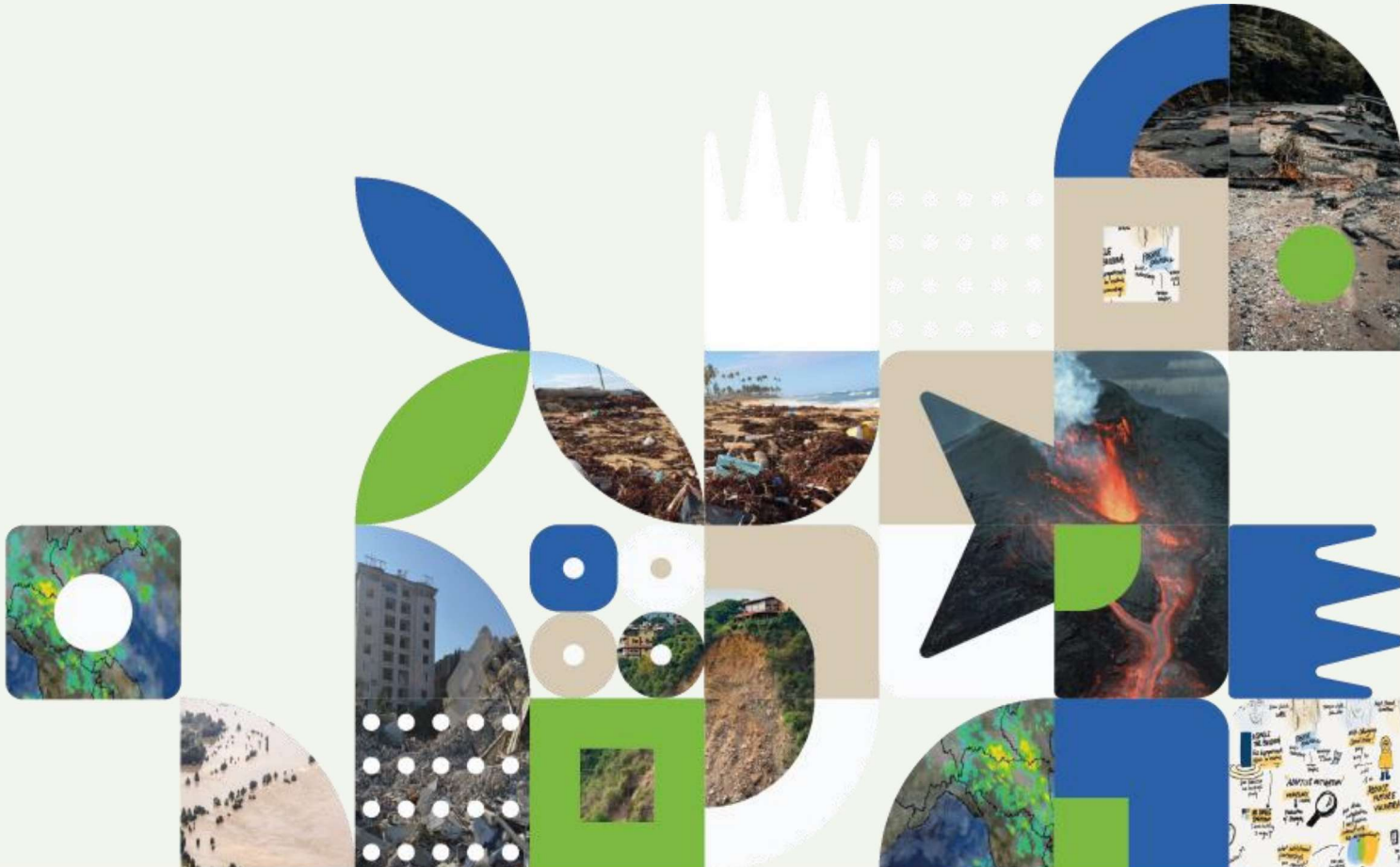
Return

Dissemination Workshop

Torino (Italy), 1-2 February 2024

BOOK OF ABSTRACTS



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Beyond NaTECH risk: safety and resilience in Hythane transport infrastructure

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A technological accident initiated by a natural disaster is known as NaTech (Natural hazard triggering technological disasters). Today, such events are a topic of great interest and concern due to the increase in the intensity of weather-related phenomena, caused mainly by climate change and as a lack of management of the territories and their vulnerabilities. The RETURN (Multi-Risk sciEnce for resilienT commUnities undeR a changiNg climate) project funded under the PNRR is dedicated specifically to improving the entire disaster risk management cycle. As a POC, part of TS2 - Multi Risk Resilience of Critical Infrastructures, a NaTECH risk analysis of Hythane transport infrastructure was performed.

Hythane is a hydrogen-enriched methane mixture that is used as a potential bridge solution to reduce CO_2 emissions. The use of this mixture brings several immediate benefits in terms of emissions and the investment associated with the development of suitable infrastructure, which is significantly lower than for pure hydrogen. Therefore, the use of hydrogen in the form of Hythane could be the perfect solution for the near future. Nevertheless, the challenges associated with the use of Hythane must be kept in mind, namely the economic feasibility compared to the use of pure methane as well as safe storage and transport. The use of Hythane in transport and distribution networks, while tempting, must be properly weighed up by first conducting studies on the safety of the mixture and comparing it with the use of methane alone, but also on the compatibility of Hythane with current infrastructures.

To this end, a quantitative risk analysis (QRA) of Hythane pipelines was performed as the CH_4/H_2 ratio changes, using a specific framework for NaTech scenarios. Earthquakes, floods, and lightning strikes were assessed as natural events and loss of containment (LOC) triggers. Specific vulnerability models from the literature were used to assess the frequency of pipeline damage associated with natural events (Cozzani et al., 2014). These models were also used to determine the correct type of damage (catastrophic rupture or hole) and to understand the actual presence of an LOC. After assessing the frequency of occurrence of the LOC, the event tree analysis (ETA) was developed to assess the frequency of occurrence of the consequences. For the flooding event, the analysis showed no probability of failure associated with a mechanical fault, even under severe conditions, resulting in a zero value for the LOC frequency and thus concluding the analysis. In the case of a seismic event, the ETA results were atmospheric dispersion, vapour cloud explosion (VCE) and jet fire; however, in the case of a lightning strike, only jet fire, as a flammable material is released with a consistent probability of instantaneous ignition.

Once the frequency of occurrence of the possible consequences has been calculated, the associated consequences are analysed. To assess the consequences of jet fires, only empirical models were used to represent the radiant heat flux received at different distances from the point source for different CH_4/H_2 ratios. These models were applied to both seismic and lightning events and showed similar behaviour, i.e. as the mole fraction of hydrogen in the Hythane increases, the extent of the isorisk zone increases.

To modelling the release and dispersion of the Hythane mixture because of the LOC, computational fluid dynamics (CFD) simulations were carried out using a Reynolds Averaged Navier-Stokes (RANS) approach

considering 1-minute release from a 5-cm diameter hole located at the top of the pipeline. CFD simulations considered factors such as wind speed, atmospheric stability, ground conditions and release height.

Preliminary results are shown in Figure 1, where the mole fraction of hythane (80%CH_4-20%H_2) on the left and the mole fraction of hythane within the flammability limits (right), both evaluated in the z-x plane passing through the hole, are reported. Figures show that the mass of flammable hythane relative to the total mass released at t=60s is extremely limited due to the limited flow rate and the high diffusivity of the mixture, which leads to rapid mixing of the hythane with the air. These results are also compared with those obtained using empirical modelling in steady state conditions.

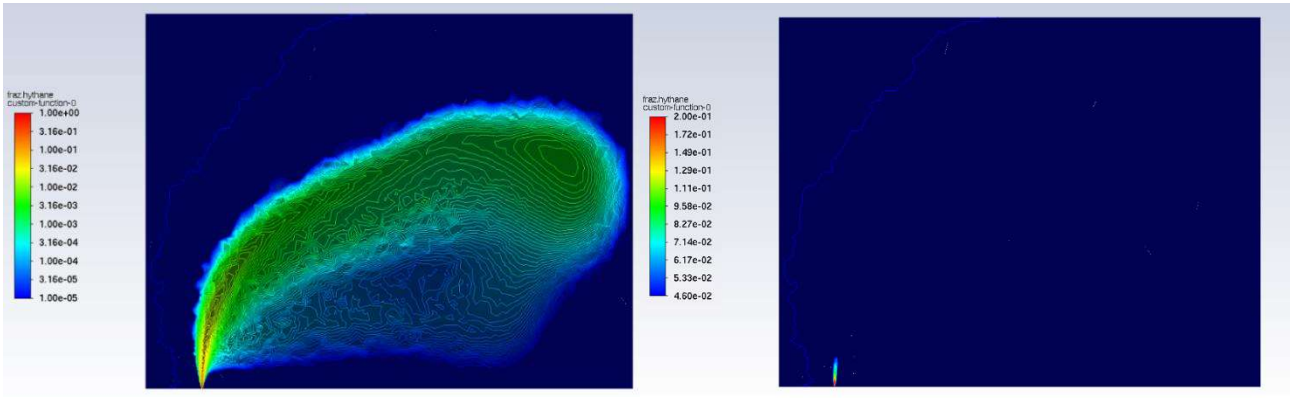

Figure 4 - Hythane dispersion in the case of H_2/CH_4= 0.25 in terms of molar fraction (left) and in terms of molar fraction included in the flammable limits (right)

To determine the optimum ratio, different CH_4/H_2 ratios that increase the hydrogen content of the mixture will also be evaluated both empirically and through CFD simulations. The results obtained will provide a solid basis for the development of proactive strategies and will contribute to improving the safety and resilience of pipelines in the face of unforeseen natural disasters. These results will be exploited in the Proof of Concept exercise related to the analysis of the distribution network and production units to support decarbonization in wide industrial area, characterized by several anthropic and natural hazards.

References

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