

Implementing Carbon Capture and Storage at Existing Gas Plants

Tackling the challenges



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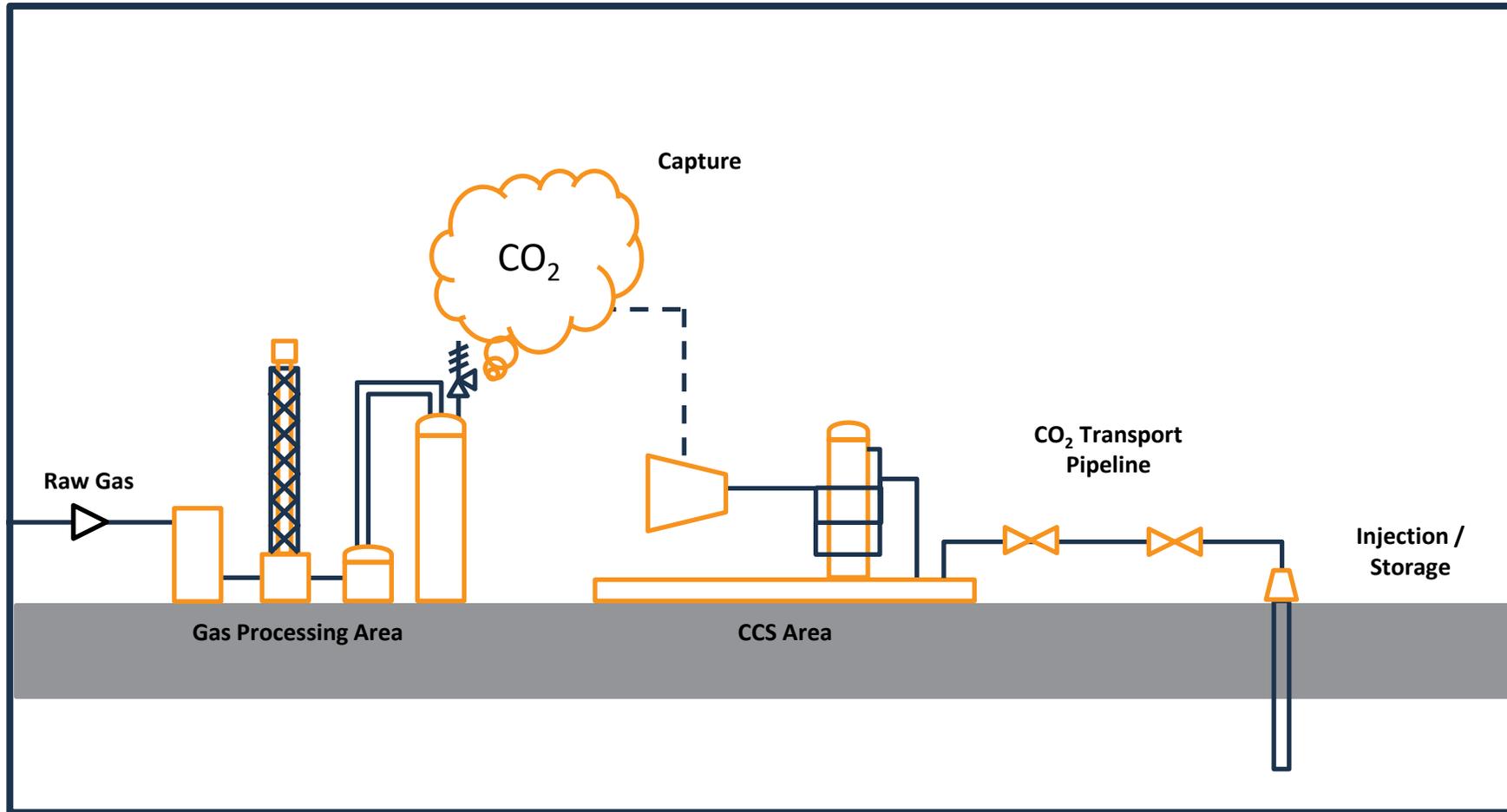
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- Carbon Capture and Storage at gas processing facilities
- Hazards profile of a gas processing facility
- Carbon Dioxide (CO₂) hazards introduced by carbon capture and storage
- Major incidents involving carbon dioxide
- Case study illustrating the significant hazard ranges introduced by CO₂ releases from future CCS operations

- Achieving greenhouse gas emission targets will require mitigation measures to remove (capture) carbon dioxide (CO₂) from process vent systems in many existing use situations.
- Carbon Capture and Storage (CCS) aims to prevent CO₂ generated by processing facilities from being released into the atmosphere
- CCS involves capturing CO₂, transporting it (usually by pipeline), and then storing it underground (typically in depleted gas reservoirs).
- Capture and compression for transportation is typically conducted on-site at an existing processing facility.

Existing plant with future CCS operations



- Hazardous materials involved in gas processing are mostly flammable primarily presenting a fire and explosion hazard
- Toxic components of raw gas are only present in relatively small quantities
 - Toxic effects of releases only likely to affect those in the immediate area
- Components of raw gas removed in processing include toxic materials such as CO₂ and hydrogen sulphide
- Whilst there is operational awareness of these toxic hazards, the safety case will typically be focussed on the major fire and explosion hazards.

- CCS incorporates handling of significant amounts of pure carbon dioxide in dense-phase (supercritical) or liquid state:
 - Significant amounts: throughput in millions of tonnes per annum (Mtpa)
 - Supercritical/liquid phase requires high-pressure – megapascals (MPa).
- A major release of pure CO₂ at these operation conditions presents a serious toxic hazard. The facility risk profile is significantly changed with the introduction of CCS
- Furthermore, the unique thermodynamic behaviour of CO₂ released at these conditions (i.e. supercritical or liquid) can lead to significantly large hazard ranges as the release is likely to remain at ground level.

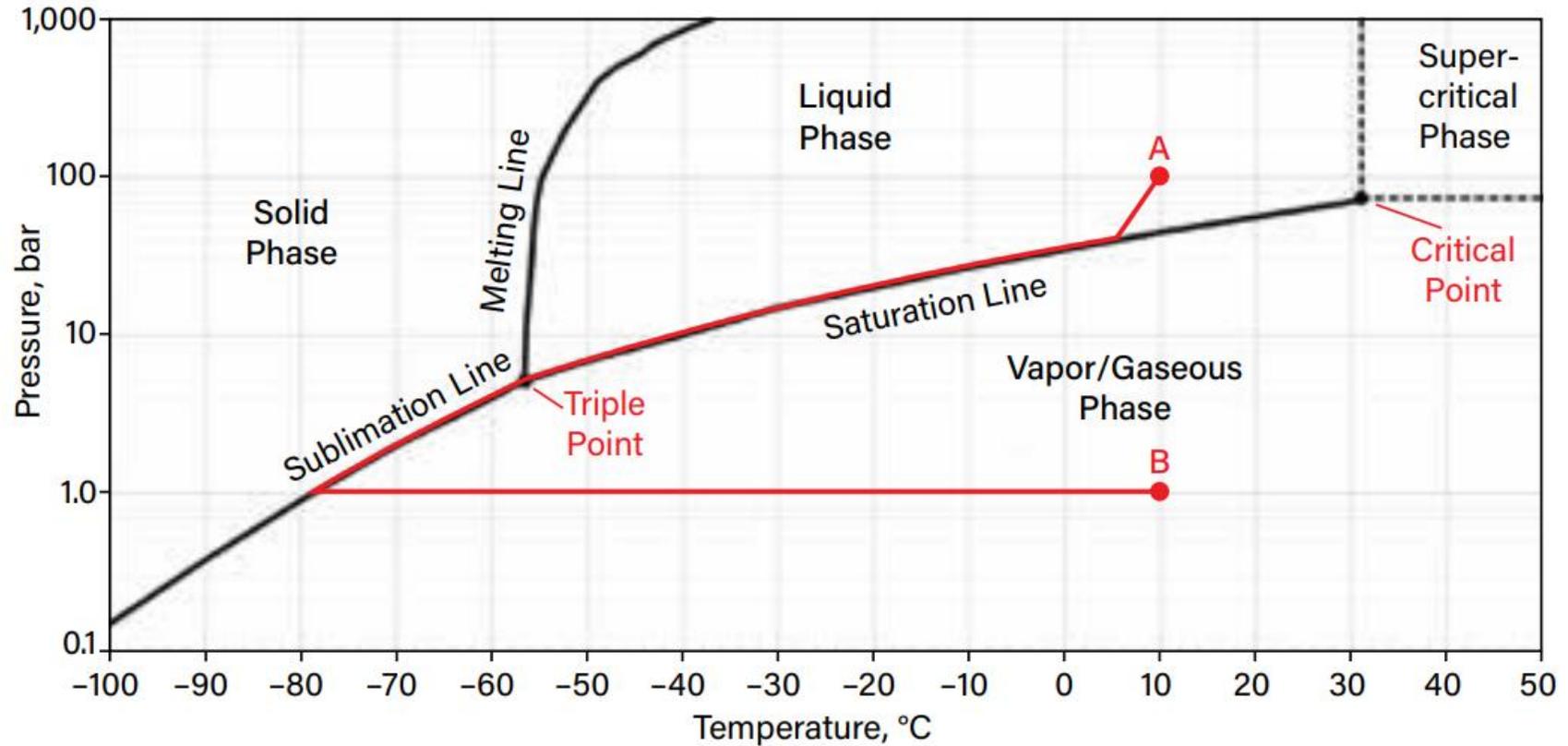
- CO₂ is considered mildly toxic as it is not harmful at low concentrations
 - Not harmful at atmospheric concentrations (~0.03 vol%).
- Toxic at higher concentrations with effects depending on concentration and exposure duration. For example,
 - **Harm Threshold:** Adverse health effects exposure limit of 3 vol% for 15 minutes
 - **Injury Threshold:** Injury potential after exposure to 4 vol% for 30 minutes
 - **Fatality Threshold:** Fatality potential after exposure to 7 vol% for 30 minutes
 - **Immediate Fatality:** Possible immediate threat to life via asphyxiation at 50 vol%.

- Pipeline ruptured, releasing liquid CO₂ that vaporize at atmospheric conditions.
- The weather conditions and unique site topography prevented the CO₂ vapour from dispersing, enabling it to flow towards a nearby town (Satartia).
- Forty-five people sought medical attention at local hospitals. No fatalities.

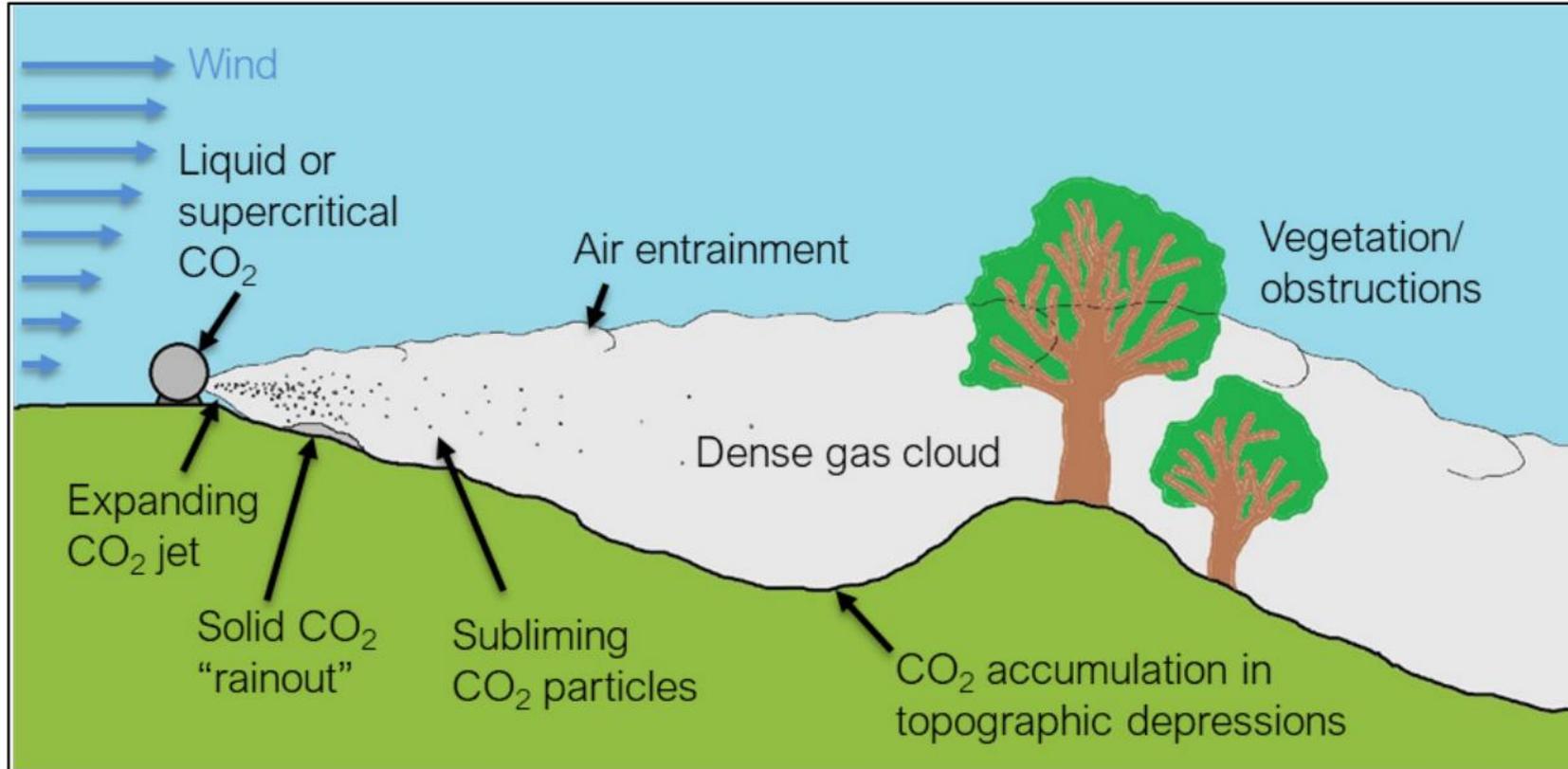


Figure 2: Vehicle is Parked on HWY 433 - The White is Ice Generated by the Release of CO₂ - The Blue Arrow Points North
(Aerial Drone Photograph Courtesy of the Mississippi Emergency Management Agency)

US Department of Transportation, PHSM, "Failure Investigation Report – Denbury Gulf Coast Pipelines LLC Pipeline Rupture/Natural Force Damage", May 26, 2022.



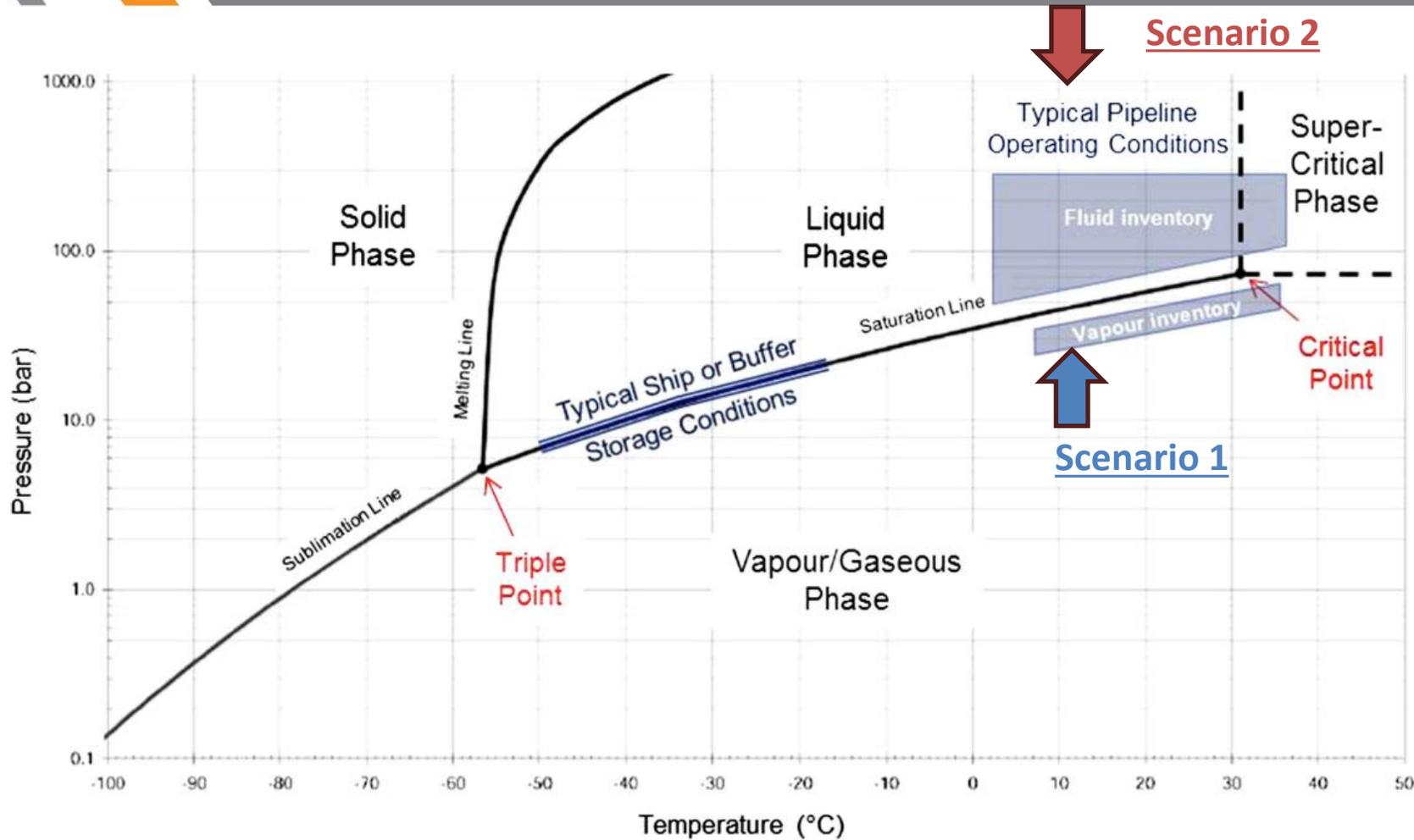
C. Spitzenberger (2023), "Carbon Dioxide Major Accident Hazard Awareness," CEP, AIChE.



DNV (2022), "Advanced CO₂ consequence modelling for safe CCS".

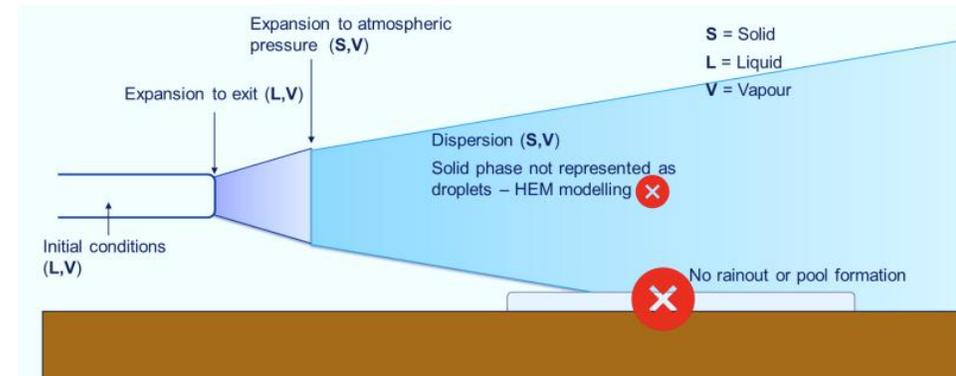
- CO₂ Major Incidents breaks down into the following key categories:
 - Source, the existing facilities
 - Capture, Compression
 - Transportation (i.e. pipelines)
- Scenario 1: Raw Gas Source to Capture
 - 50 mm release of raw gas from existing plant (i.e. 5 MPa, 30°C).
 - Composition of methane (~70%) with CO₂ (~30%)
- Scenario 2: Compression / Transportation inlet
 - 50 mm release of CO₂ from future compression facilities (i.e. 10 MPa, 30°C)

Typical Operating Conditions



DNV, "CO2 RISKMAN JIP, Guidance on CCS CO2 Safety and Environment Major Accident Hazard Risk Management, Level 3 – Generic Guidance", Report No. I3IJLJW-2, 30 January 2013, Rev. 1 (Reissued 17 December 2021, Rev 3).

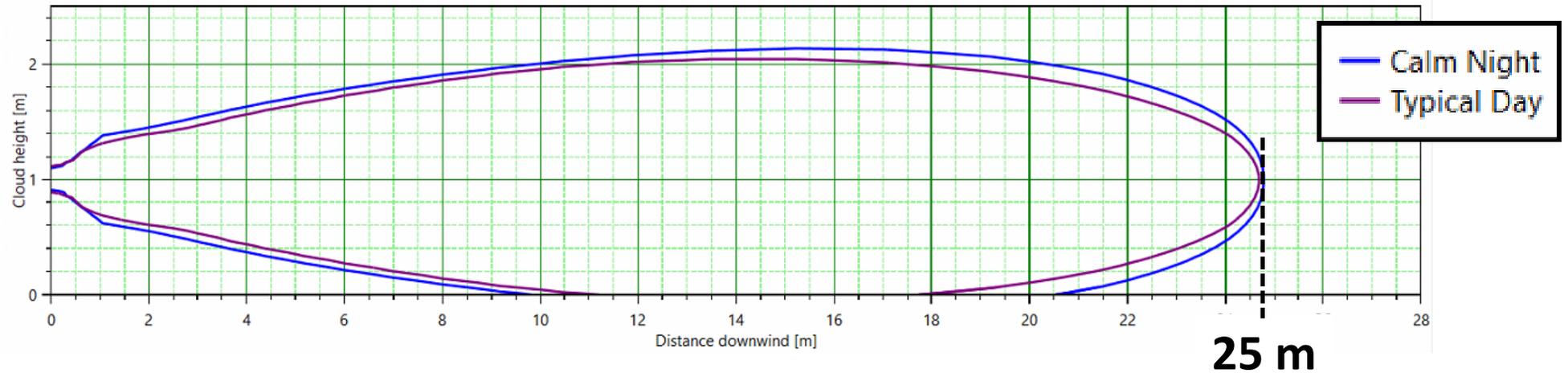
- DNV Phast software for modelling with extension to handle the fluid-to-solid transition of CO₂
 - The effect of solids formation is considered in the modelling.
- Dispersion model for horizontal releases validated against experimental data
 - CO2PIPETRANS JIP8.
 - No solid fallout.
- Model parameters:
 - Scenario-specific process conditions
 - Typical day & stable night weather conditions
 - Potential toxic effects – *Harm, Injury, Fatality & Immediate Fatality*.



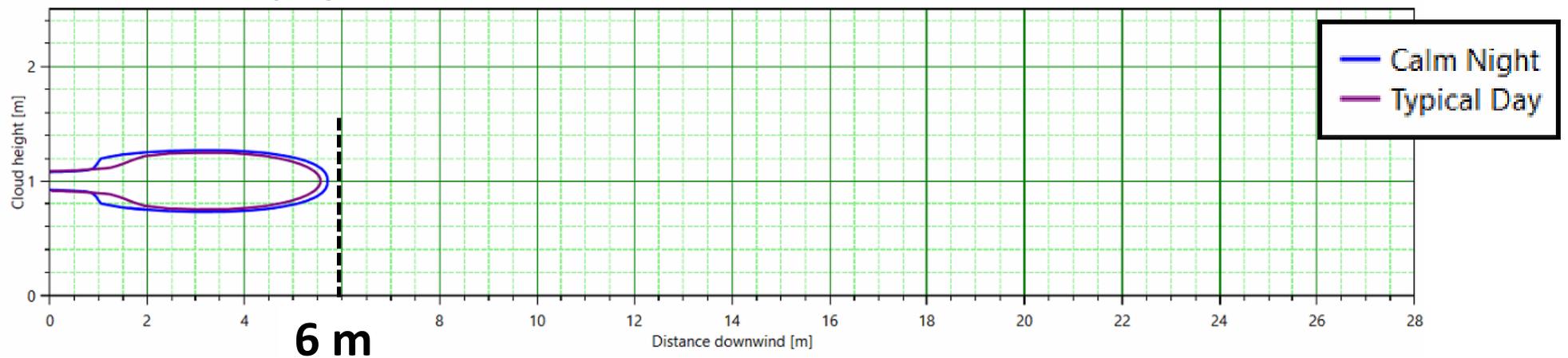
DNV (2022), "Application of Phast and Safeti to carbon dioxide consequences and risks".

Scenario 1: Raw Gas to Capture

- **Extent of Flammable Envelope:**

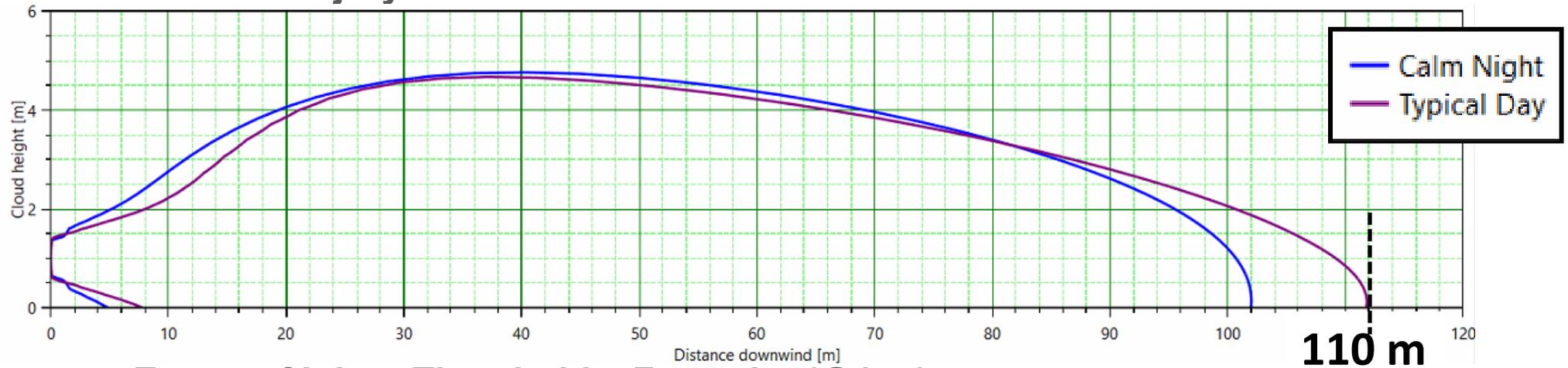


- **Extent of Injury Threshold:**

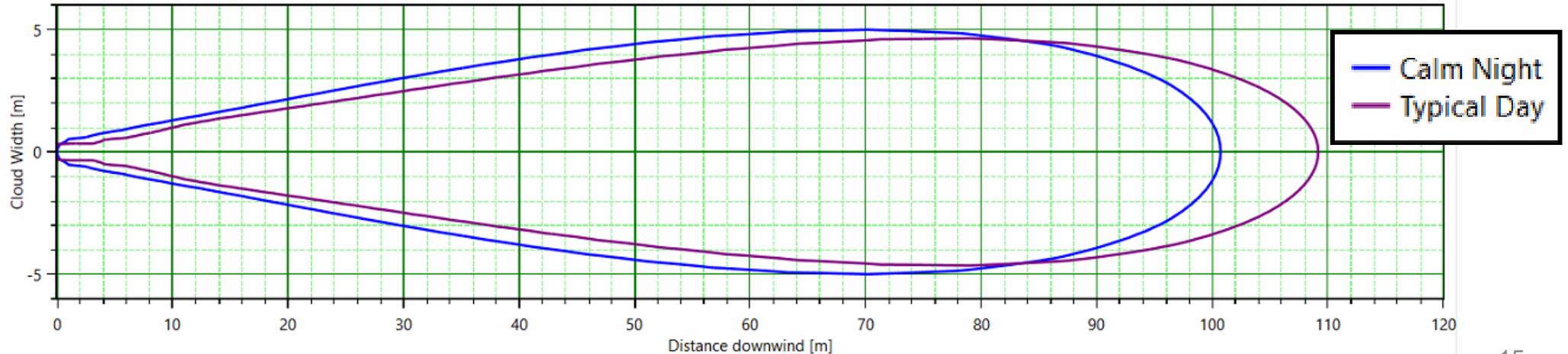


Scenario 2: Compressed CO₂ to Transport

- **Extent of Injury Threshold – Side View:**



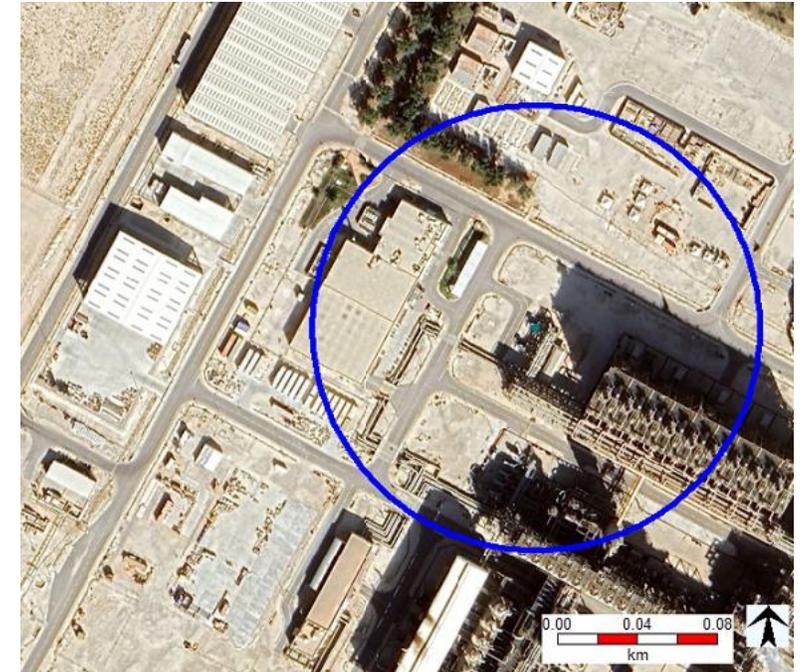
- **Extent of Injury Threshold – Footprint (@1 m):**



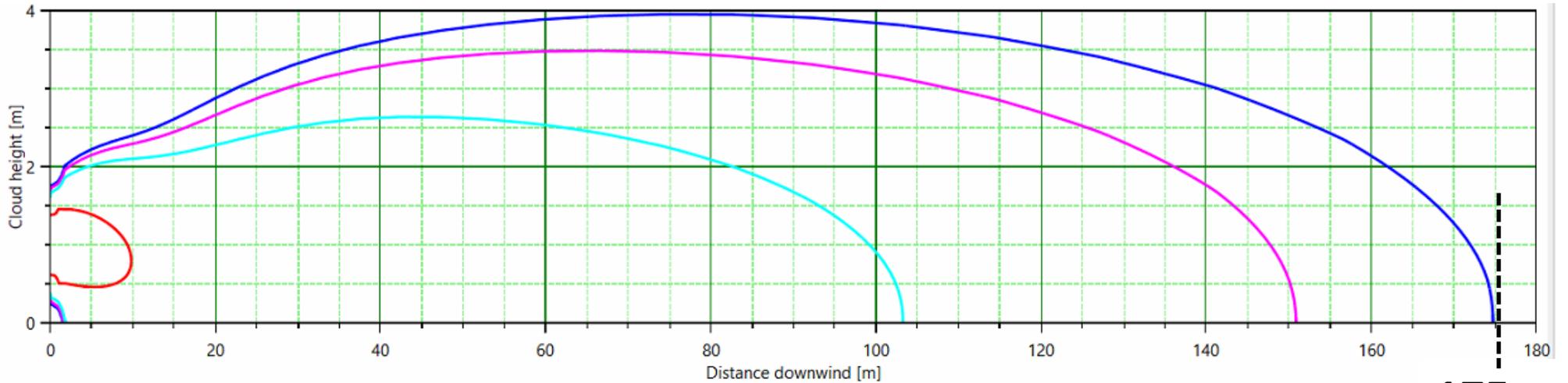
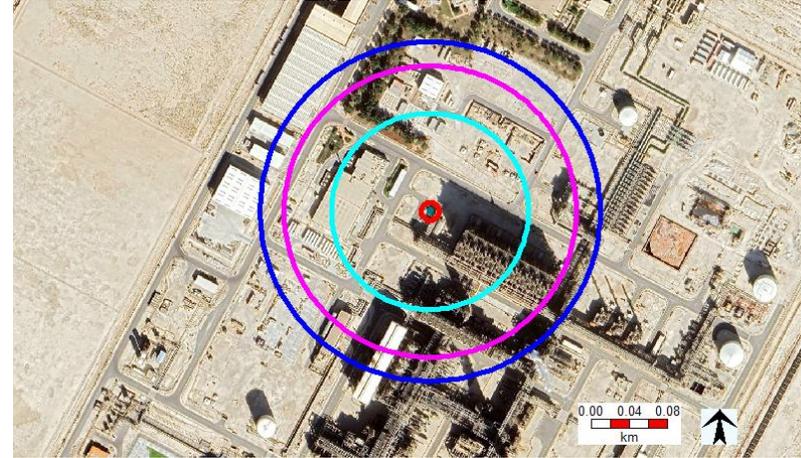
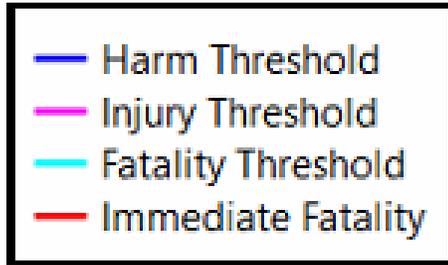
Scenario 1 Hazard Range



Scenario 2 Hazard Range



A CO₂ release from CCS facilities could impact a much larger, previously unaffected population.



175 m 7

- Update emergency response plans to incorporate strategy required in response to a CO₂ release
- PPE different from that typically used
 - Respiratory protection to cope with the toxic risk
 - Leather gloves to cope with frostbite risk
 - Hearing protection from high-pressure releases
- Training tailored to the specific needs of CO₂ releases
 - Understanding the constraints of respiration equipment and the time available
 - Enacting a buddy system so responders do not enter vapour clouds alone
- Institutions are developing ER guidance to assist operators
 - Response to events like the Denbury incident, but applicable at site too
 - API tactical guidance in responding to a pipeline CO₂ release

- Toxic hazards present different risk to personnel within buildings.
 - Toxic exposure potential for personnel in buildings surrounding the process buildings and perhaps beyond
 - New concepts introduced to operators and personnel alike
- Considerations and adjustments for on-site buildings (e.g. RP 752)
 - In response to a toxic release, is sheltering in place or evacuating safer?
 - How long can I stay indoors before needed to exit?
 - What additional PPE personnel protective equipment does it require?
- Are existing buildings capable of serving as effective toxic refuges?
 - Ensuring buildings are airtight: sealing windows, doors, and penetrations.
 - HVAC systems capable of shutdown.
 - Systems to notify personnel (indoor and outdoor) of air concentration levels.

- Releases pose a significant toxic hazard, distinct from traditional hazards at gas processing plants.
- CO₂ used in large quantities combined with its unique physical properties increases the potential risk
- CO₂ release scenarios could expose personnel to harmful concentrations in the plant and nearby areas.
 - May involve large numbers of people who were not previously exposed to plant hazards.
- Insights can be used to update emergency response plans for potential CO₂ release impacts at CCS facilities.

Thank you



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