Risk assessment in the framework of Blue Hydrogen

Federica Tamburini - *PhD-student at NTNU*

In recent years, the global concentration of carbon dioxide in the atmosphere has increased drastically due to the continuous consumption of fossil fuels. With the aim of curbing climate change and meeting the increasingly stringent net-zero emission targets, blue hydrogen technology may be seen as the short-term decarbonization strategy in the prolonged period of the energy transition. In this context, the climate mitigation potential of blue hydrogen technologies derives from its peculiarity of coupling steam methane reforming (SMR) in existing plants with carbon dioxide capture and sequestration (CCS) technique. The potential introduction of this new technology in civil and industrial applications implies the presence of unexplored safety aspects that are fundamental for its effective implementation. For this reason, the present research project aims at developing a consistent quantitative risk assessment (QRA) methodology and a thorough evaluation of the safety associated with systems for blue hydrogen production.

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Federica Tamburini

PhD candidate

NTNU – Norwegian University of Science and Technology

MTP – Department of Mechanical and Industrial Engineering

Research activity outline

Introduction

The global warming issue

Blue Hydrogen

The low-carbon solution supporting the energy transition

Carbon dioxide Capture and Sequestration (CCS)

The crucial short-term decarbonization strategy

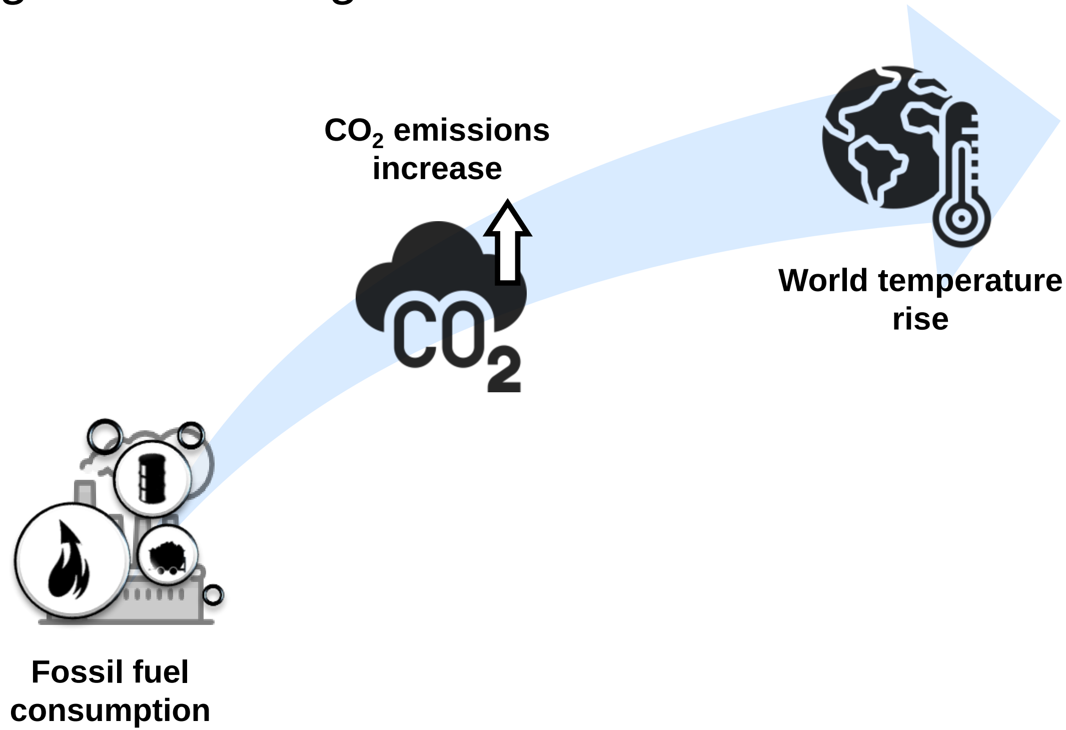
Risk assessment approaches

CO_2 transport and storage steps

Conclusions and future developments

Introduction

The global warming issue



Climate changes

- Sea level rise
- Wildfires
- Water shortage
- Biodiversity loss
- Crop failure
- Extreme weather

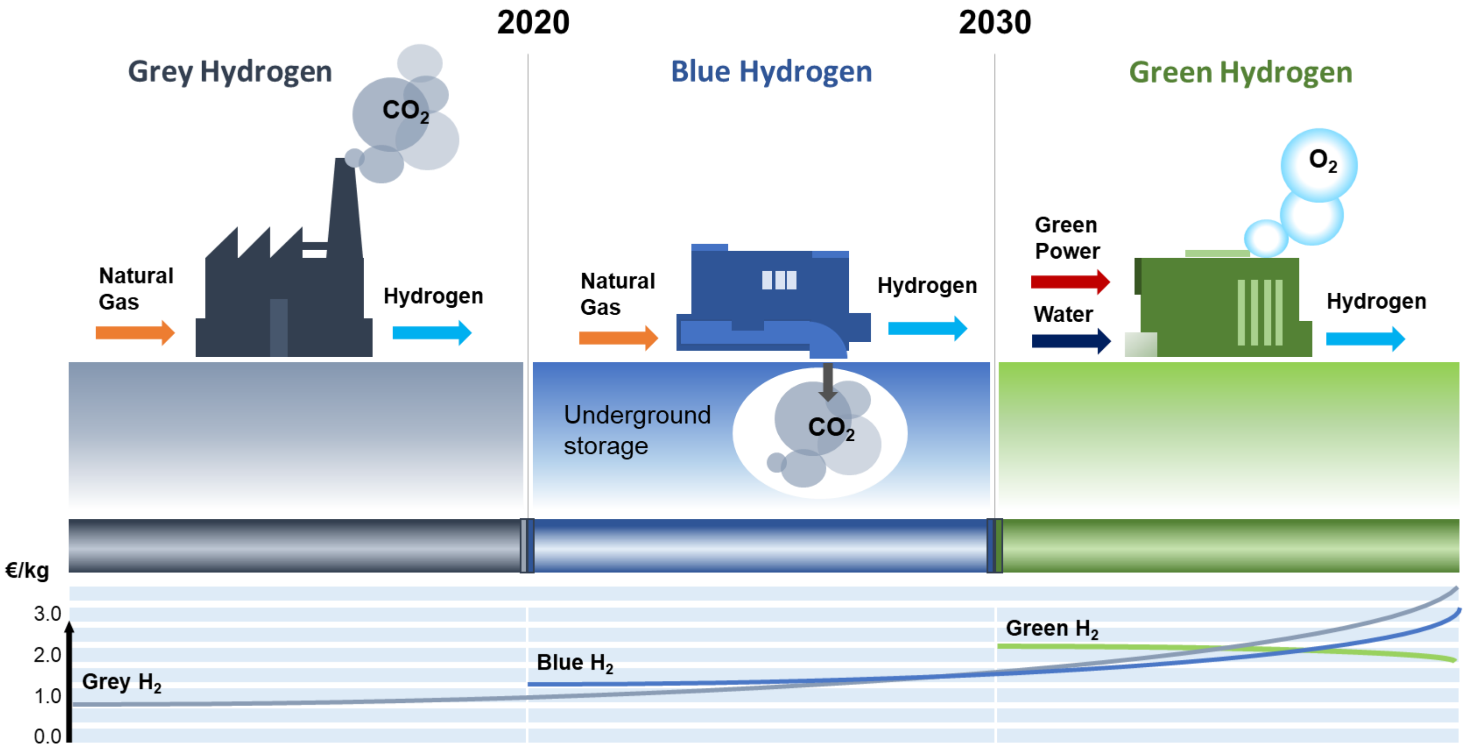
Consequences

- Spread of diseases
- Increased risk of wars and conflicts
- Impacts on human rights

…**urgent** decarbonization **actions MUST** be **taken**!

Blue Hydrogen (1)

The low-carbon technology supporting the energy transition



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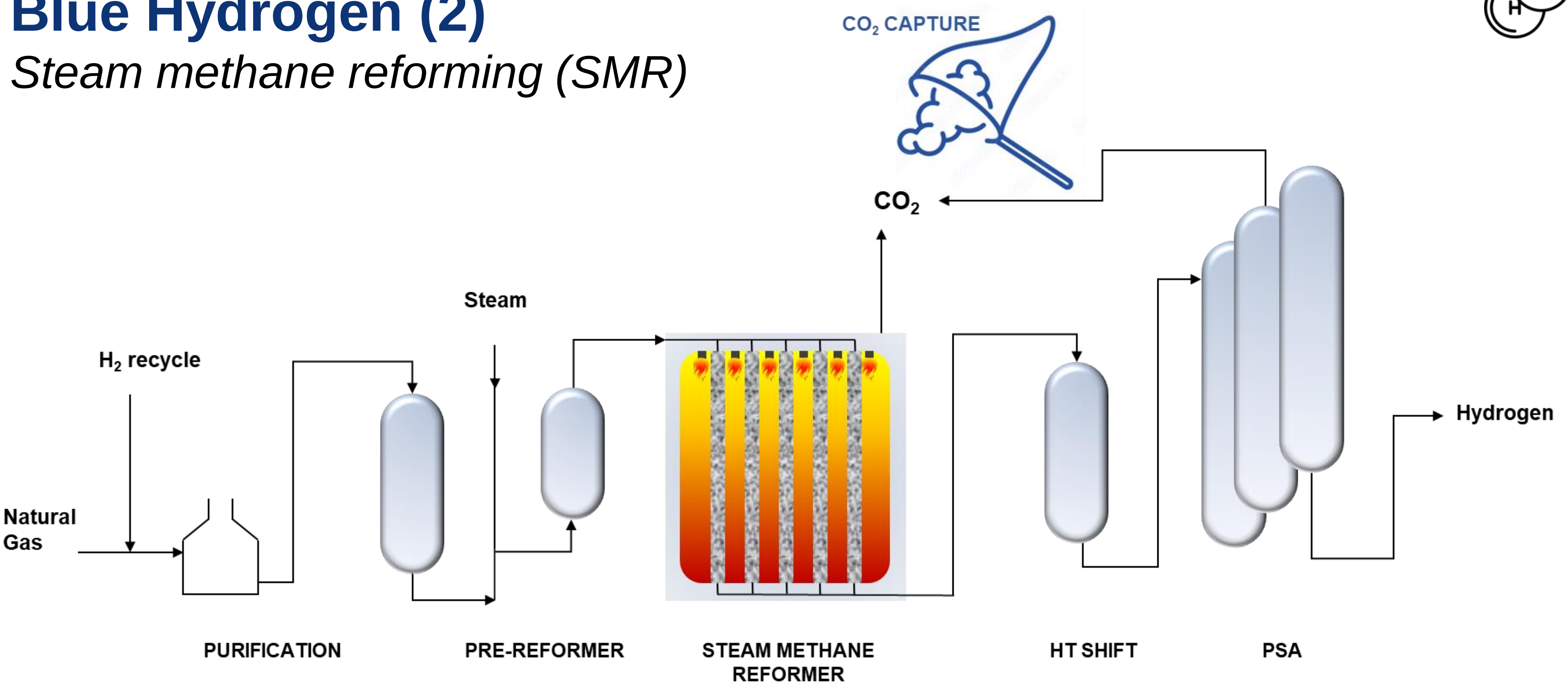
Blue Hydrogen (2)

Steam methane reforming (SMR)



$CH_4 + H_2O \rightarrow CO + 3H_2$

$CO + H_2O \rightarrow CO_2 + H_2$

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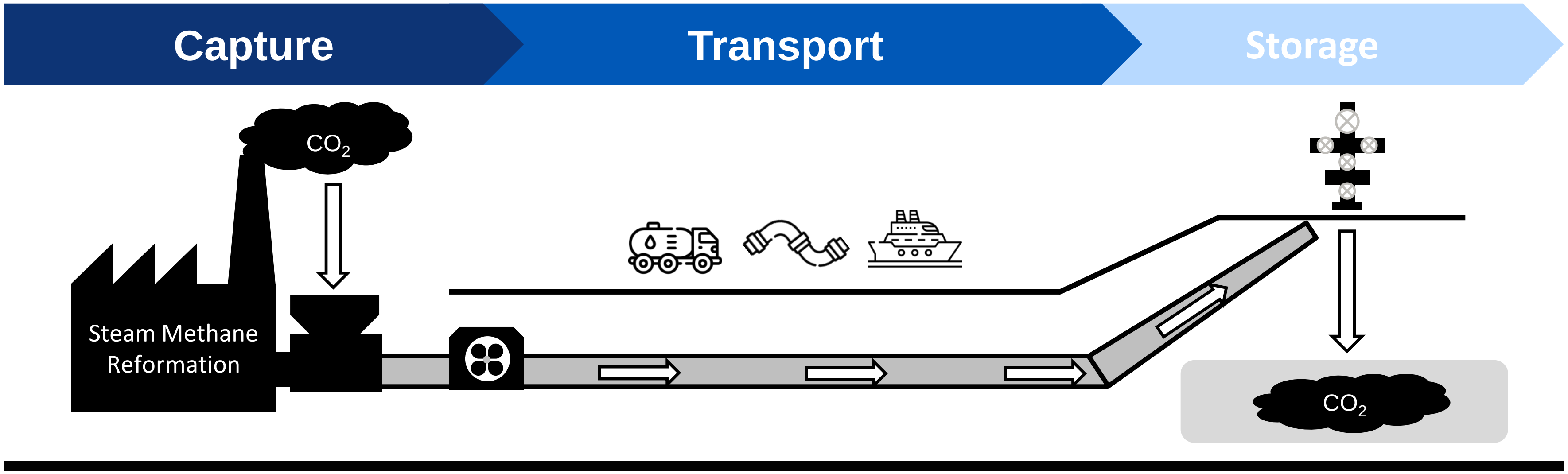
Carbon dioxide Capture and Sequestration (CCS)

The crucial short-term decarbonization strategy



1

Capture plants take effluent streams **from steam methane reformer** and separate the offtake into CO_2 and other substances

2

The purified and compressed **CO_2** is **pipelined**, **trucked** or **shipped** to the sequestration site

3

The pure **CO_2** is **injected** into rock formations **deep underground**

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Risk assessment approaches (1)

CO_2 dangerous characteristics

For humans, CO_2 is both a **mildly toxic** and a **physical stressor**:

- ✓ toxicity thresholds: $LC50_{hmn,30min}$ = 92000 ppm, IDLH = 40000 ppm
- ✓ cold burns threshold: -18 °C

For assets, CO_2 is a **physical stressor**:

- ✓ cold embrittlement
- ✓ erosion due to abrasive solid dry ice particles

For the marine biota, CO_2 is a **toxic stressor**:

- ✓ pH ↓

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Risk assessment approaches (2)

Definitions

Blowout: uncontrolled release of oil and/or gas from wells after pressure control systems failures

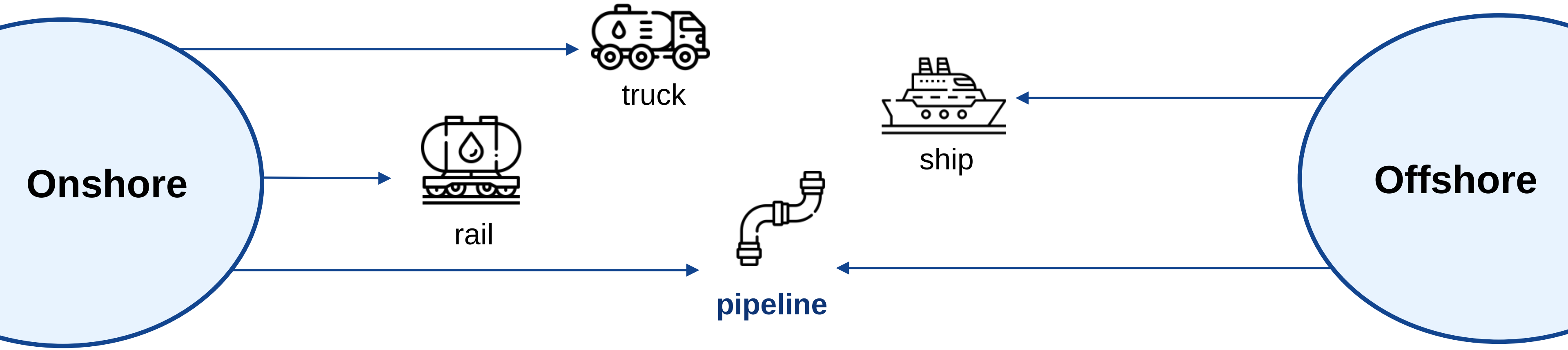
When a wellhead blowout scenario occurs …

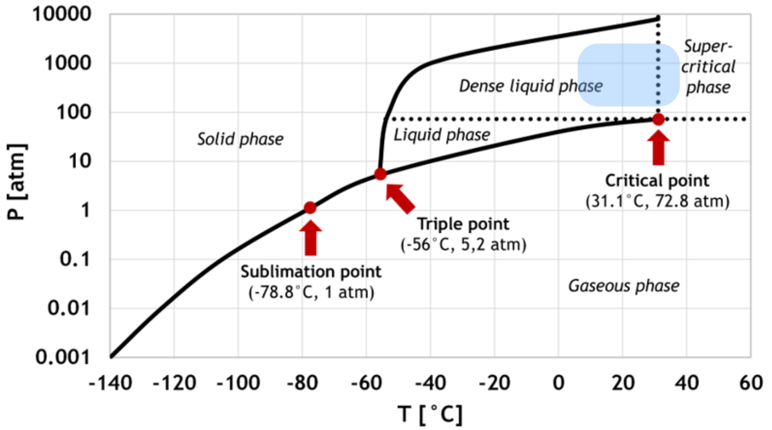
… the workers or animals located in the surrounding of the accident are at **RISK**

Probability of occurrence × **Severity of harm** = **RISK**

Risk assessment approaches (2)

CO_2 transport modes





Risk assessment approaches (3)

Pipeline consequence analysis

Tools for consequence modelling

- **Source term**
  - **Onshore**
    - **PHAST** DNV GL
    - **EFFECTS** GEXCON
    - **OLGA** SCHLUMBERGER
  - **Offshore**
    - **OLGA** SCHLUMBERGER
- **Dispersion**
  - **Onshore**
    - **PHAST** DNV GL
    - **EFFECTS** GEXCON
  - **Offshore**
    - **TAMOC** TEXAS A&M UNIVERSITY

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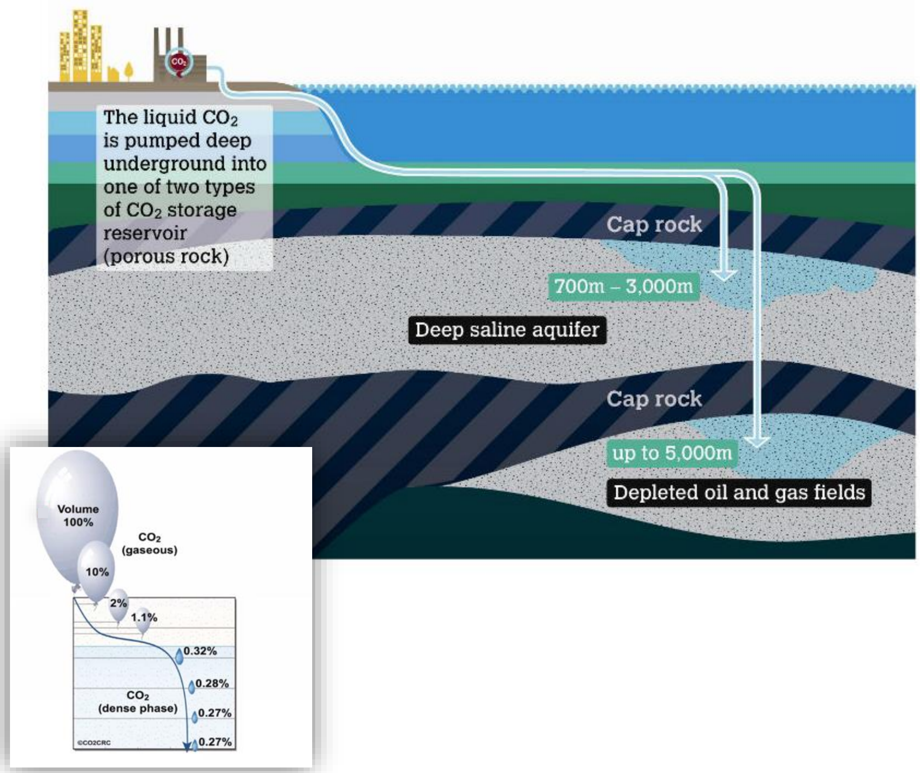
Risk assessment approaches (4)

CO_2 storage sites



Europe

In the **North Sea**
- Saline aquifers

In the **Adriatic Sea**
- Depleted natural gas fields

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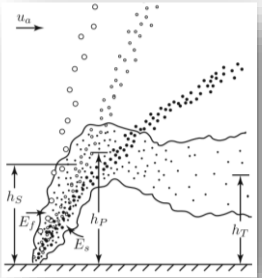
Risk assessment approaches (5)

Injection well consequence analysis

Tools for consequence modelling

- **Source term**
  - **Offshore**
    - **OLGA** – SCHLUMBERGER
    - **T2Well** – LAWRENCE BERKELEY NATIONAL LABORATORY
- **Dispersion**
  - **Onshore**
    - **PHAST** – DNV GL
    - **EFFECTS** – GEXCON
  - **Offshore**
    - **TAMOC** – TEXAS A&M UNIVERSITY
    - **MIKE ECOLab** – DHI



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Conclusions and future developments

- Based on the peculiarities of CO_2, the adoption of more detailed consequence analysis tools (e.g., CFD) is suggested to strengthen the quantitative risk assessment structure
- Validation of consequence modelling tools against experimental data
- Improvement of the TAMOC code to account for two phases (liquid-vapour and solid-vapour) releases from CO_2 sealines

- Study of the Blue Hydrogen value chain
- Multi-objective analysis of the single step of the chain (i. e., bunkering process)
- Investigation into rapid phase transition and bleve phenomena

Thank you for your attention!

Federica Tamburini

NTNU – Department of Mechanical and Industrial Engineering (MTP)

federica.tamburini9@unibo.it