RAMS & HYDROGEN SAFETY

A PEEK AT OUR OVERARCHING VISION

NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY

KNOWLEDGE FOR A BETTER WORLD

TRONDHEIM | GJØVIK | ÅLESUND

NTNU

RAMS group

RAMS (reliability, availability, maintainability, safety) Group at the Department of Mechanical and Industrial Engineering

5+2 faculty members - 2 Post doc – 15+ PhDs – 50 master students

Jørn Vatn

Shen Yin

Viggo Gabriel Borg Pedersen

Nicola Paltrinieri

Yiliu Liu

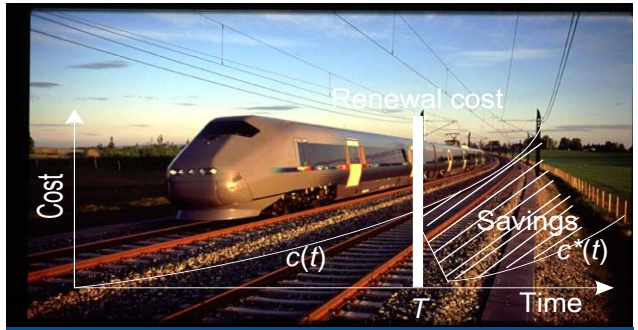
Pillar research areas

- Reliability system engineering
- Risk assessment
- Maintenance
- Safety & Security

Energy

Offshore

Production



Civil

Healthcare

RAMS specialization and International RAMS master program

RAMS specialization in 5-year PuP program
6-8 Norwegian student
2-year International RAMS master program
14-18 students, including 2-5 Norwegians

Reliability, Availability, Maintainability and Safety

Photo: Unsplash

Faculty of Engineering
Department of Mechanical and Industrial Engineering

FACTS

Degree: Master of Science in Engineering
Duration: 2 years, 120 ECTS
Programme code: MSRAMS
Restricted admission: Yes
Language of instruction: English

Faculty of Engineering
Mechanical and Industrial Engineering

City: Trondheim

This information is relevant for the present academic year.

https://www.ntnu.edu/studies/msrams

NTNU Norwegian University of Science and Technology

1. Year

Autumn — Compulsory and elective courses

Code	Name	SP	Status
TPK4120	Safety and Reliability Analysis	7.5	O
TPK4140	Maintenance Management	7.5	O
TPK5115	Risk Management in Projects	7.5	O
TPK5165	RAMS Engineering and Data Analytics	7.5	O

Spring — Compulsory and elective courses

Code	Name	SP	Status
TDT4127	Programming and Numerics	7.5	M1A
TPK4186	Advanced Tools for Performance Engineering	7.5	M1A
TPK5120	Elements of Model Engineering	7.5	O
TPK5160	Risk Analysis	7.5	O

2. Year

Autumn — Reliability, Availability, Maintainability and Safety - 2nd year

Code	Name	SP	Status
SPRÅK3501	Scientific Communication for Engineers	7.5	M1A
TPD4142	Design Thinking	7.5	M1A
TSOL425	Technology Management in Teams	7.5	M1A
TTM4185	Security and robustness in ICT systems	7.5	M1A
TPK4450	Digitalized Solutions to Prognosis, Predictive Maintenance an...	7.5	O
TPK4550	Reliability, Availability, Maintainability and Safety, Specializati...	15	O

show less

Spring — Reliability, Availability, Maintainability and Safety - 2nd year

Code	Name	SP	Status
TPK4950	Reliability, Availability, Maintainability, and Safety, Master's Th...	30	O

Expertise:

Process safety; Risk-based predictive maintenance; Consequence modelling; Hydrogen transport and storage.

Prof. Nicola Paltrinieri

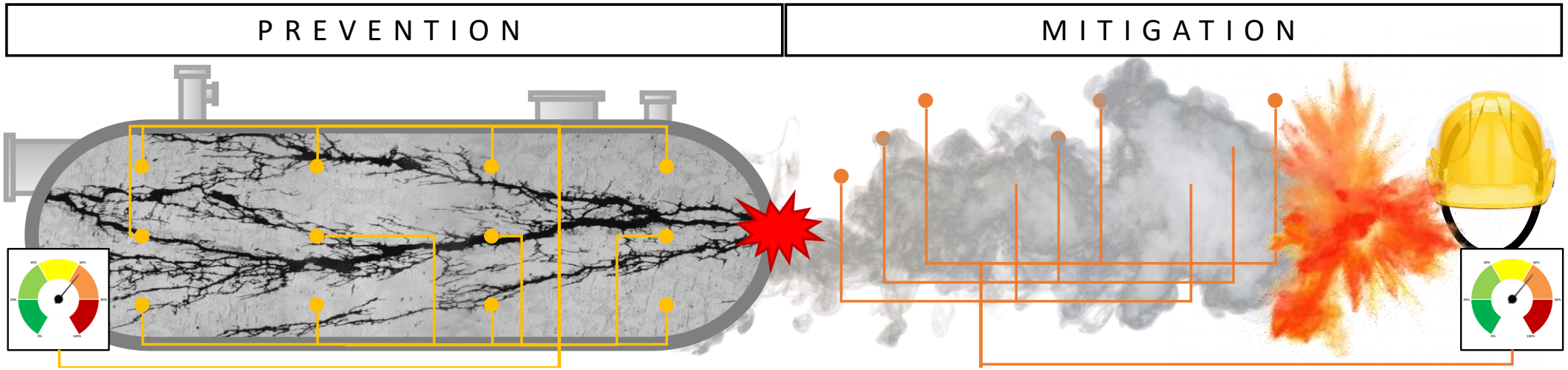
Mechanical and Industrial Engineering

https://www.ntnu.edu/employees/Nicola.paltrinieri

Nicola.paltrinieri@ntnu.no

Research interests: Data analytics for risk analysis; Hydrogen safety

Research description:



Support to design and monitoring for prognostics, i.e. predicting the time for loss of containment associated to the risk of an accident.

For **risk-based predictive maintenance.**

Sensor networks to detect and locate a release, for dynamic consequence analysis.

For **detection of early warnings and emergency response.**

Current funded research projects:

- H2 Coop Storage - Development of tools enabling the deployment of a hybrid hydrogen and electric storage solution on a district scale. Funded through the European Joint Programming Platform ERA-Net Smart Energy Systems.
- H2IFT – Safe H2 Fuel Handling and Use for Efficient Implementation. Funded by the NFR (ENERGIX)

Energy

Public sectors

RAMS Engineering

M - Maintenance

- Degradation modeling and prognosis
- Asset management and maintenance optimization

R - Reliability Systems Engineering

- Reliability and resilience engineering methods
- Safety-critical systems (barriers engineering)

S – Risk management

- Risk-informed decision-making

Research methodologies

Data analytics | **Probabilistic modeling** | **OR & optimization**

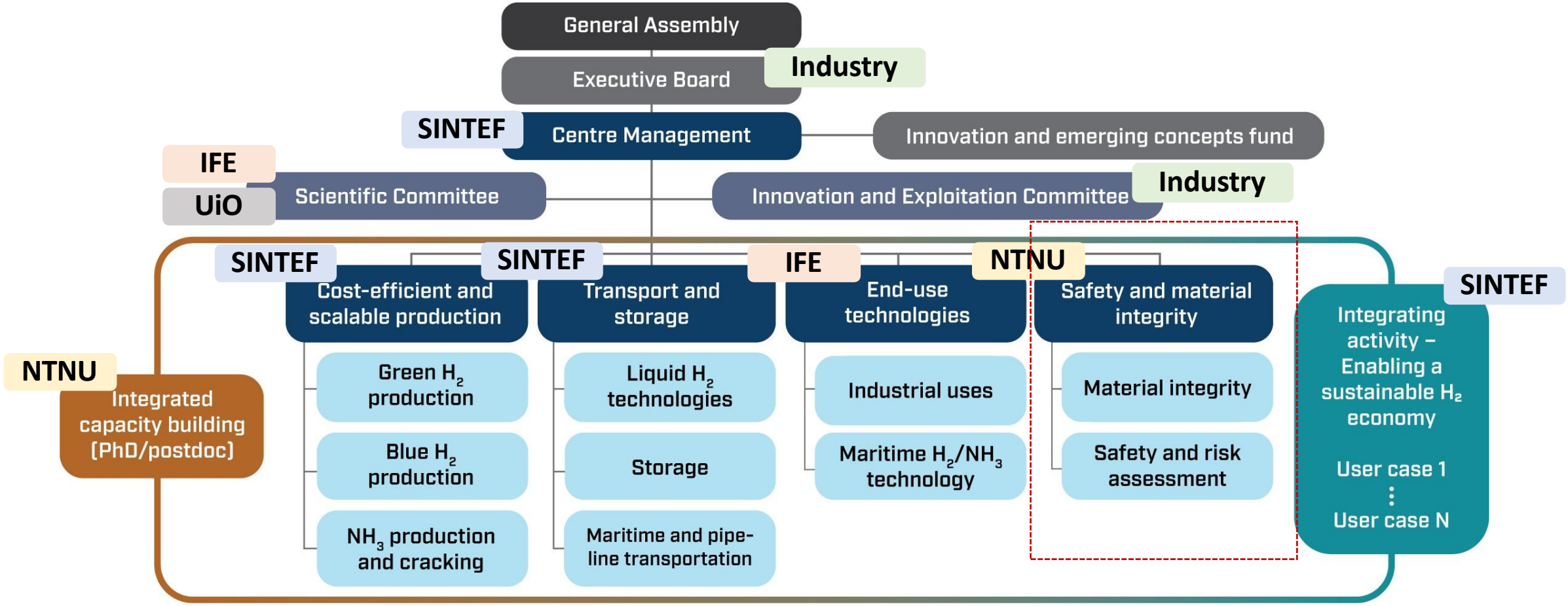
Domain Knowledge

Yiliu Liu

PhD, Professor in RAMS engineering

Hydrogen safety

FME Hydrogeni



RA4 – Safety and material integrity

- WP 4.1 – Material integrity
  - H uptake and diffusion
  - Critical degradation mechanisms
  - Lifetime assessment
  - Polymer ageing
- WP 4.2 – Safety and risk assessment
  - Risk-management framework
  - Frequency analysis
  - Physical phenomena

RA4 lead
Nicola Paltrinieri, NTNU

Hydrogen properties

Property	Value
Gravimetric energy density (MJ/kg) [3]	119.96
Combustion products	Water, NOx (avoidable)
Toxic	No
Density at NTP (kg/m^3) [4]	0.0883
Minimum ignition energy (mJ) [5]	0.017
Flammability range in air (%vol) [6]	4 ÷ 75
Flame visibility	Scarce
Colour and/or odour	None
Molecule diameter (pm)	120

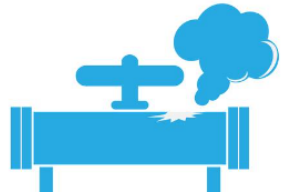
Volatile (safety)

Storage issue

Highly flammable

Difficult to detect

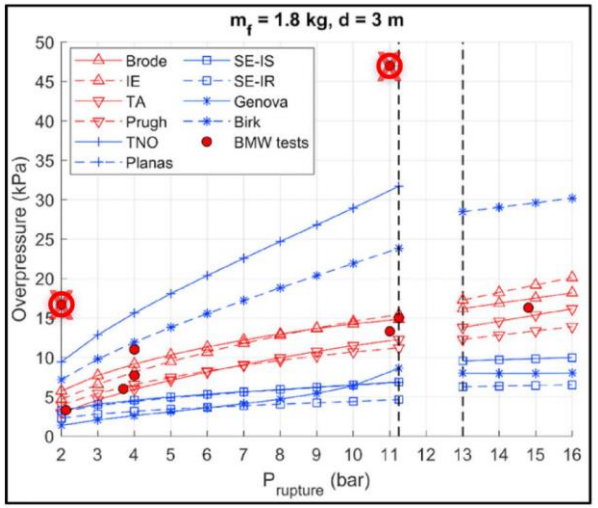
Difficult to contain

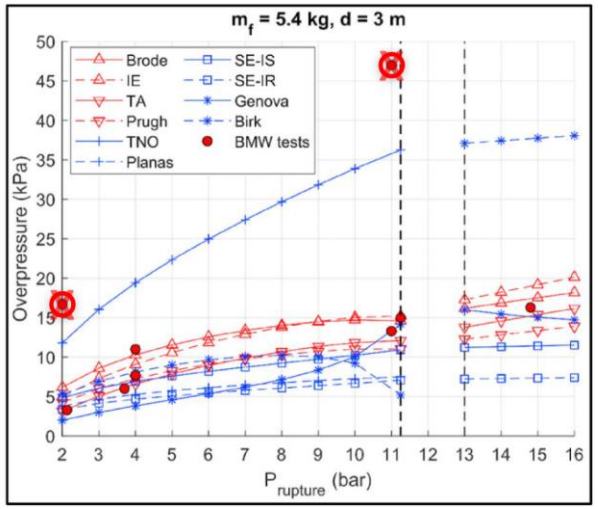


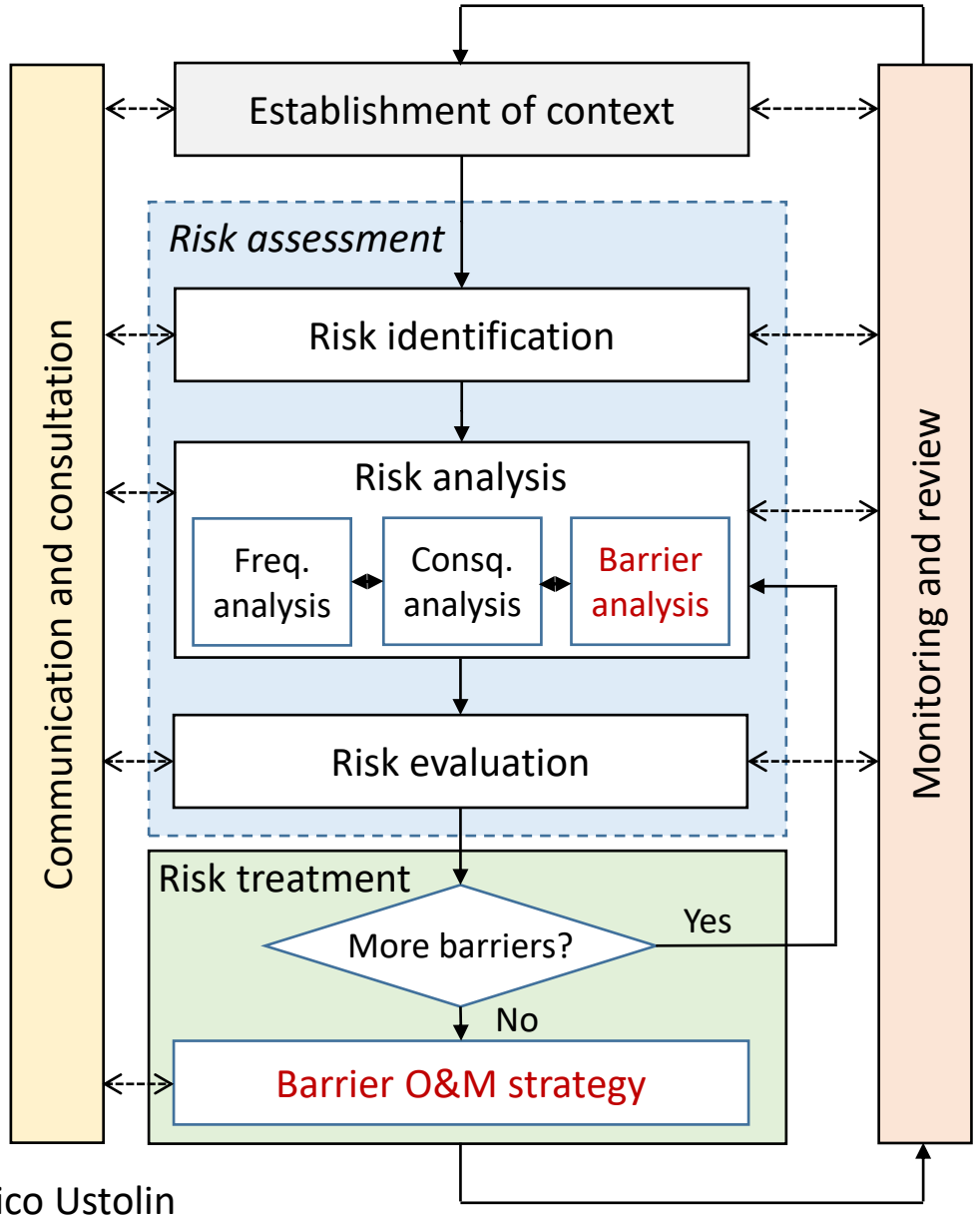
by Federico Ustolin

Risk management

Consequence analysis

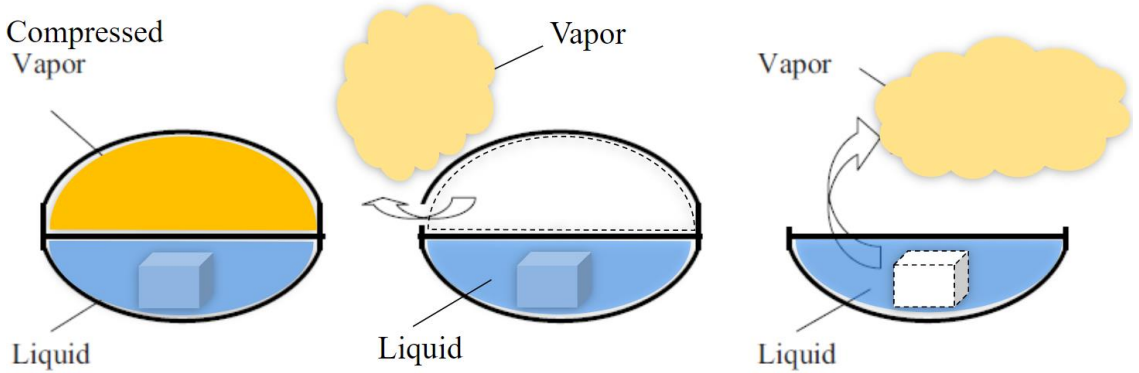


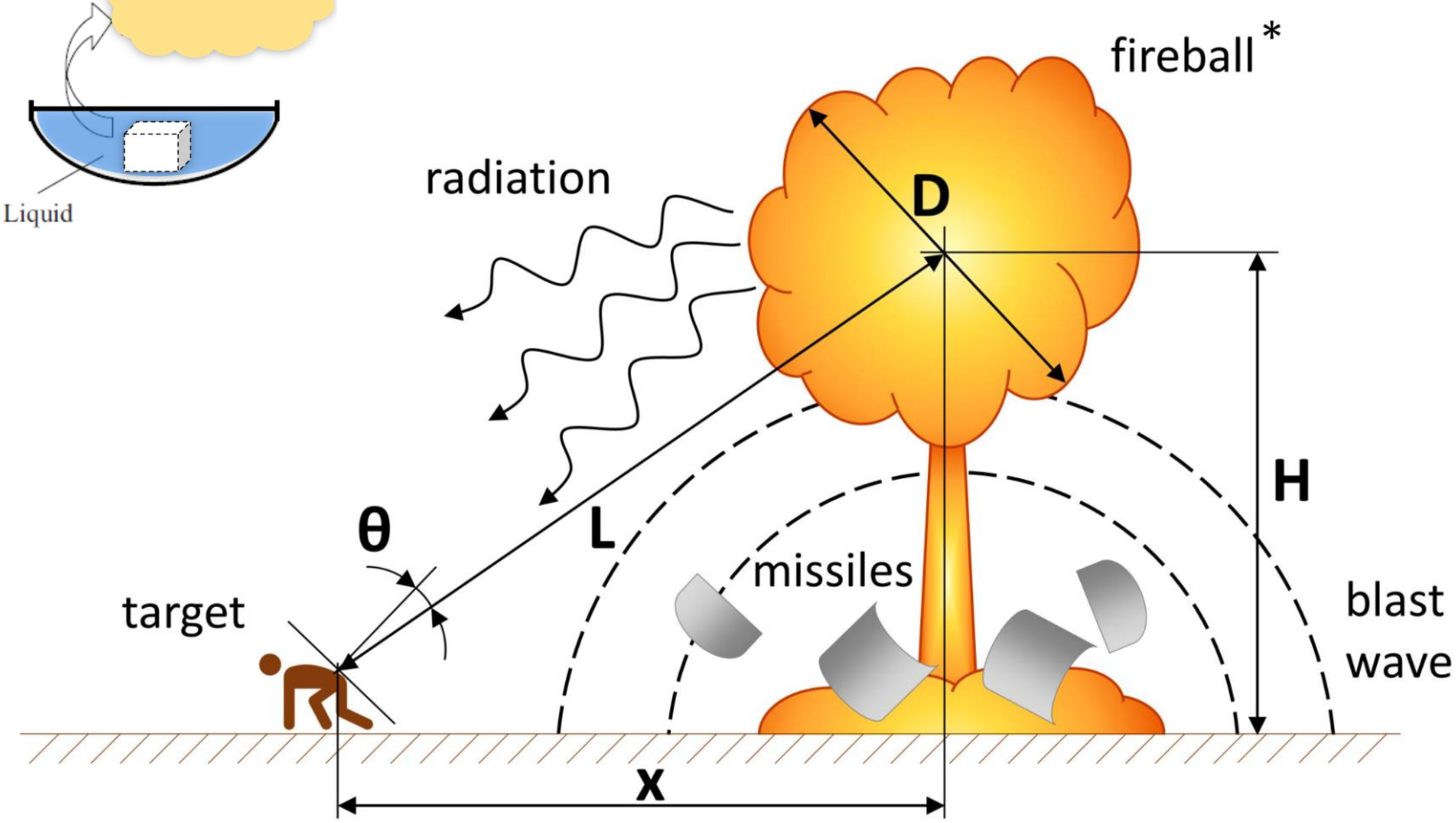




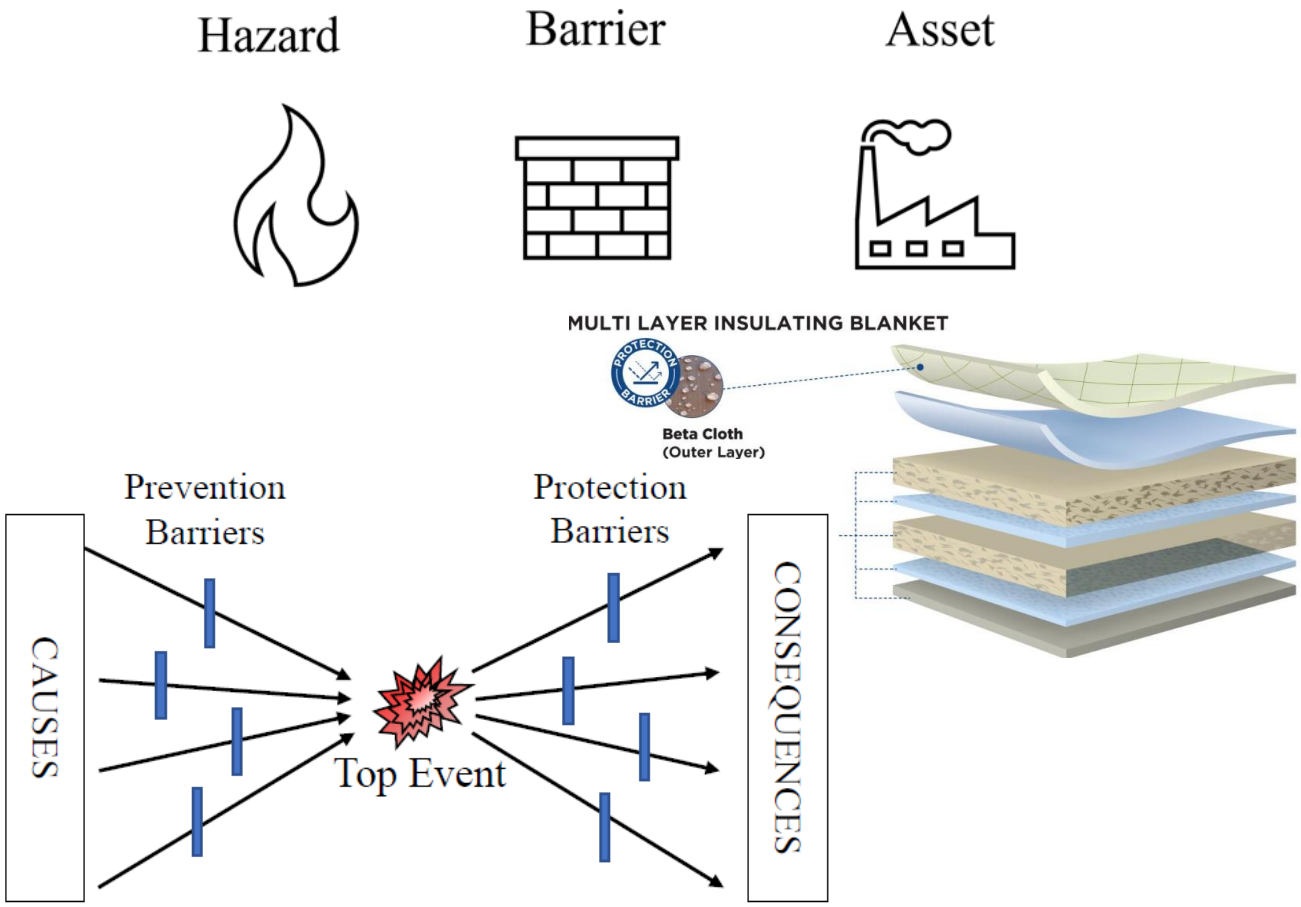
TNT equivalent mass to convert mechanical energy to overpressure, by Federico Ustolin

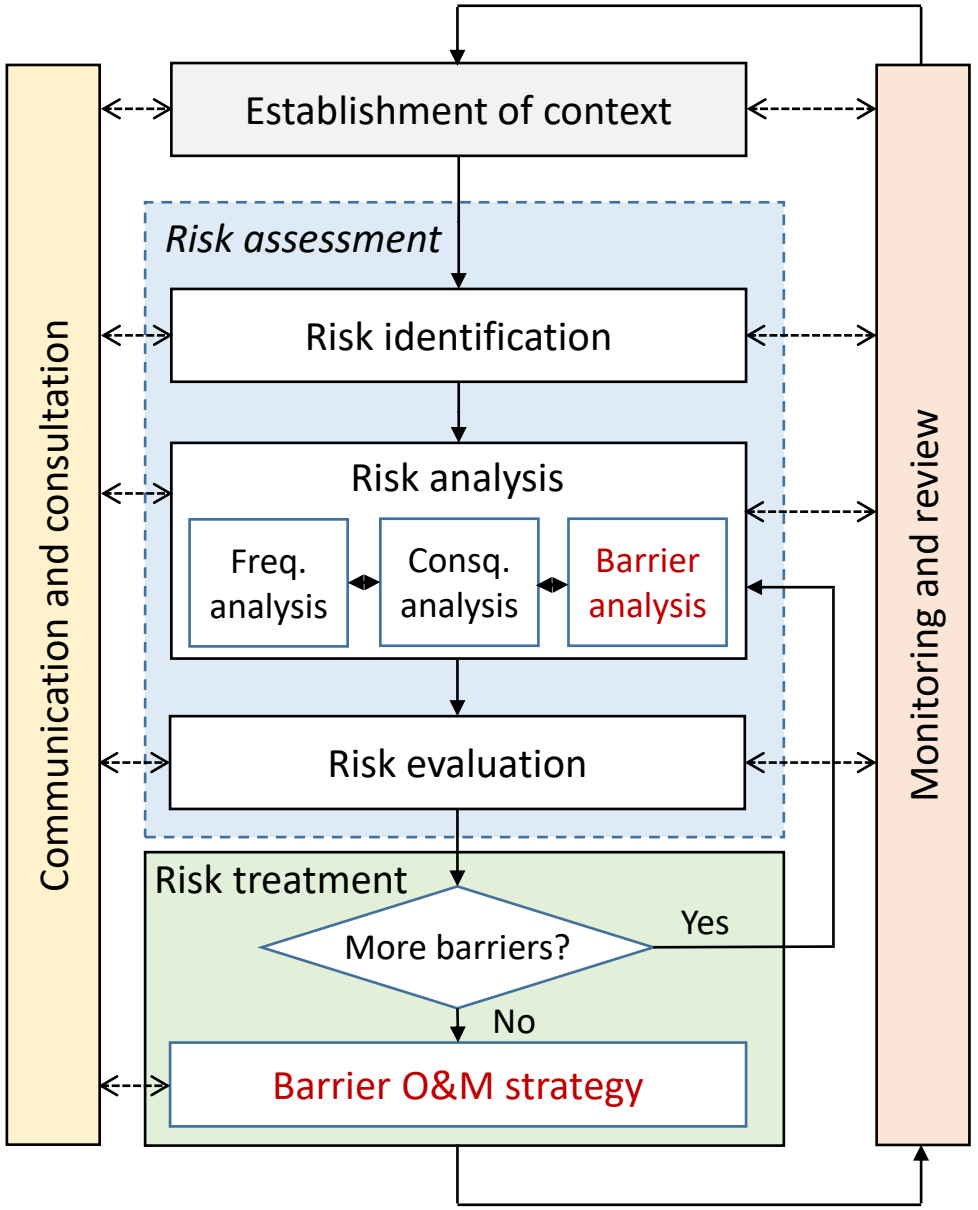
Boiling Liquid Expanding Vapour Explosions



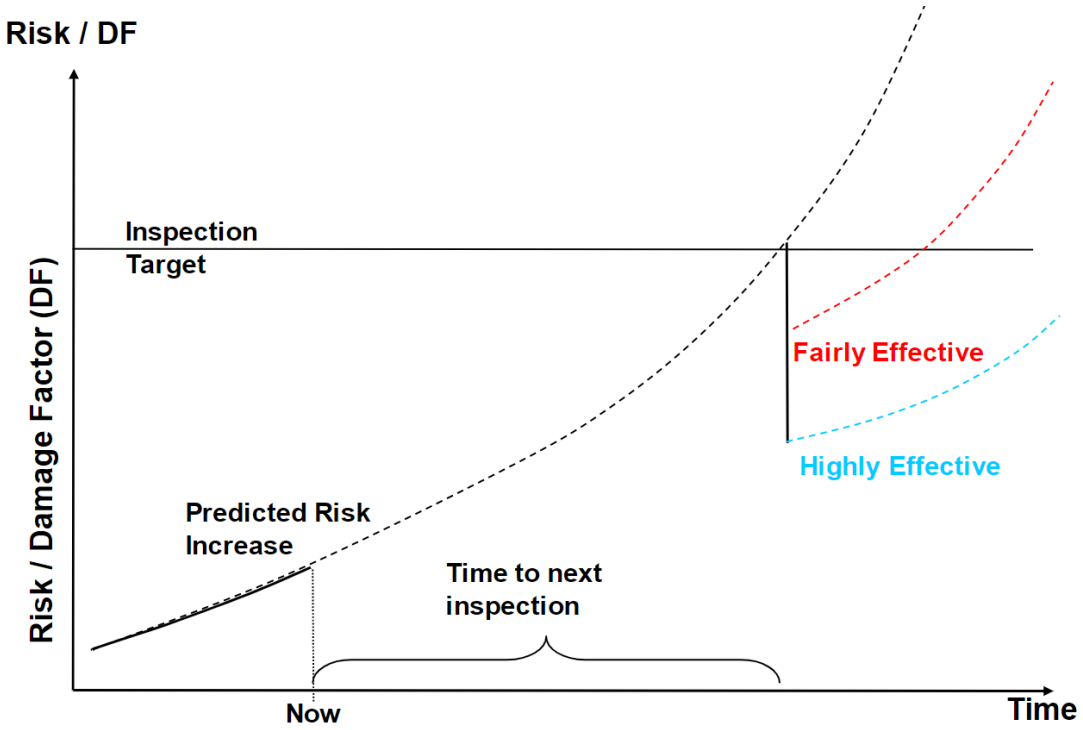


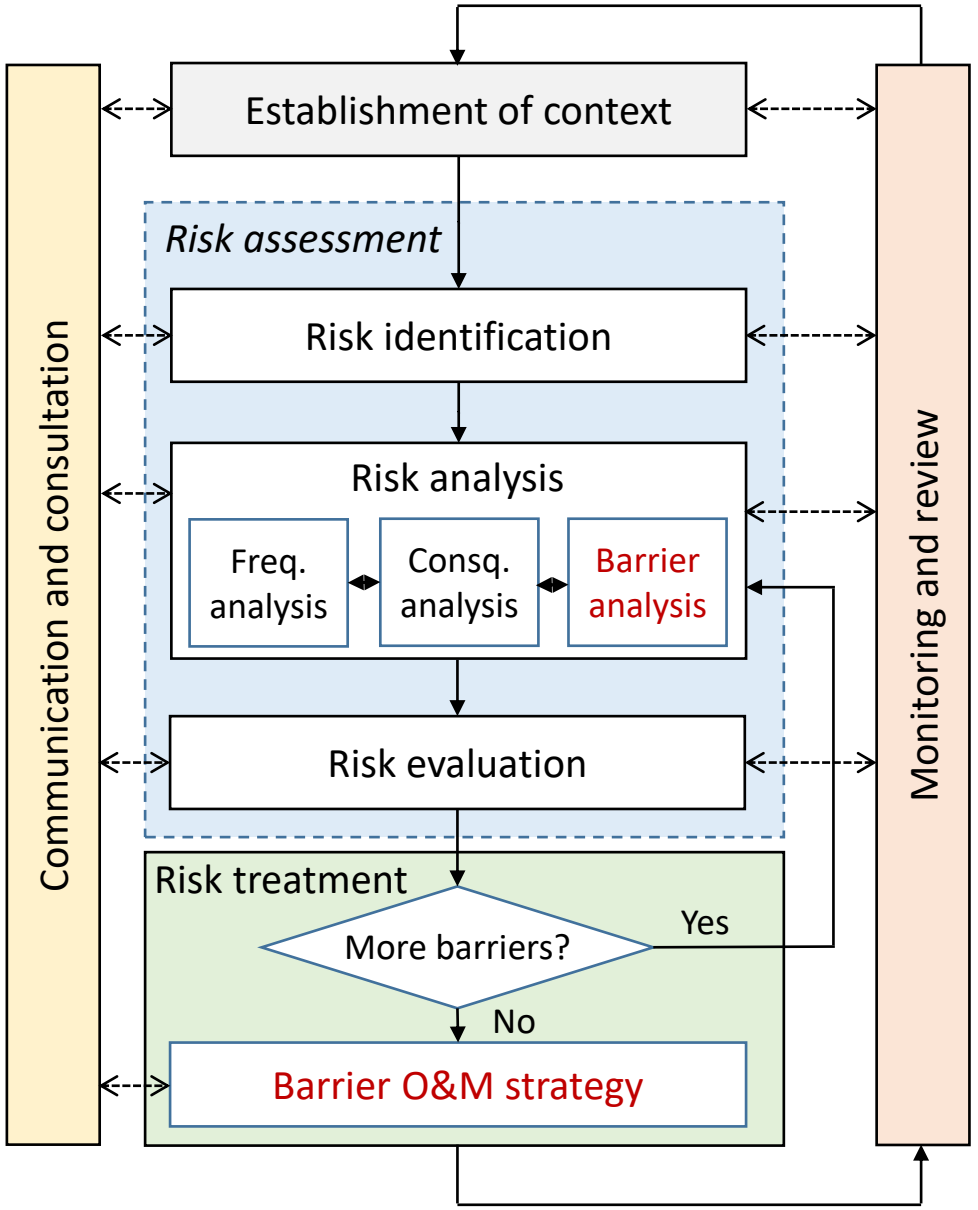
Risk management





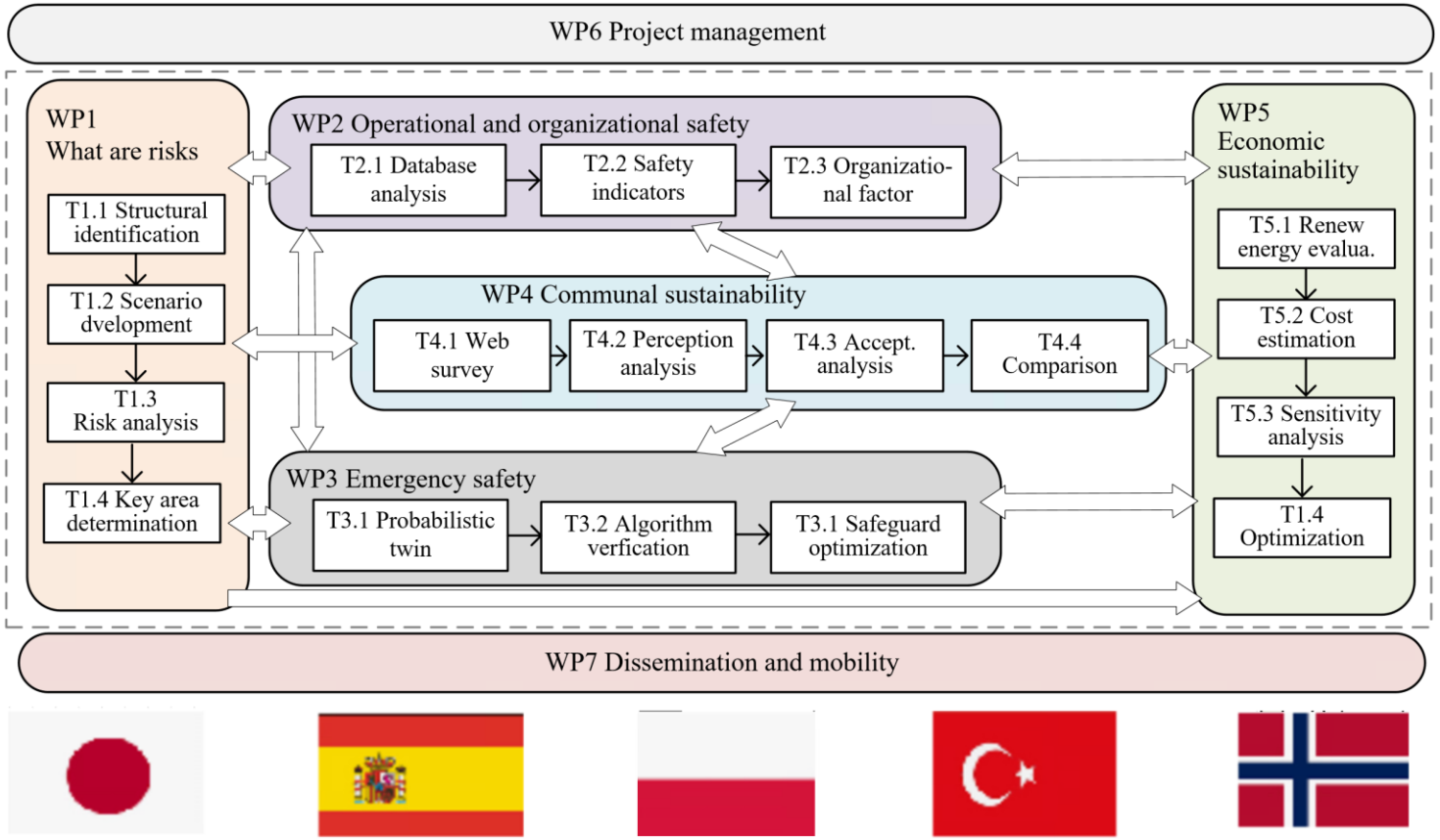
Risk management





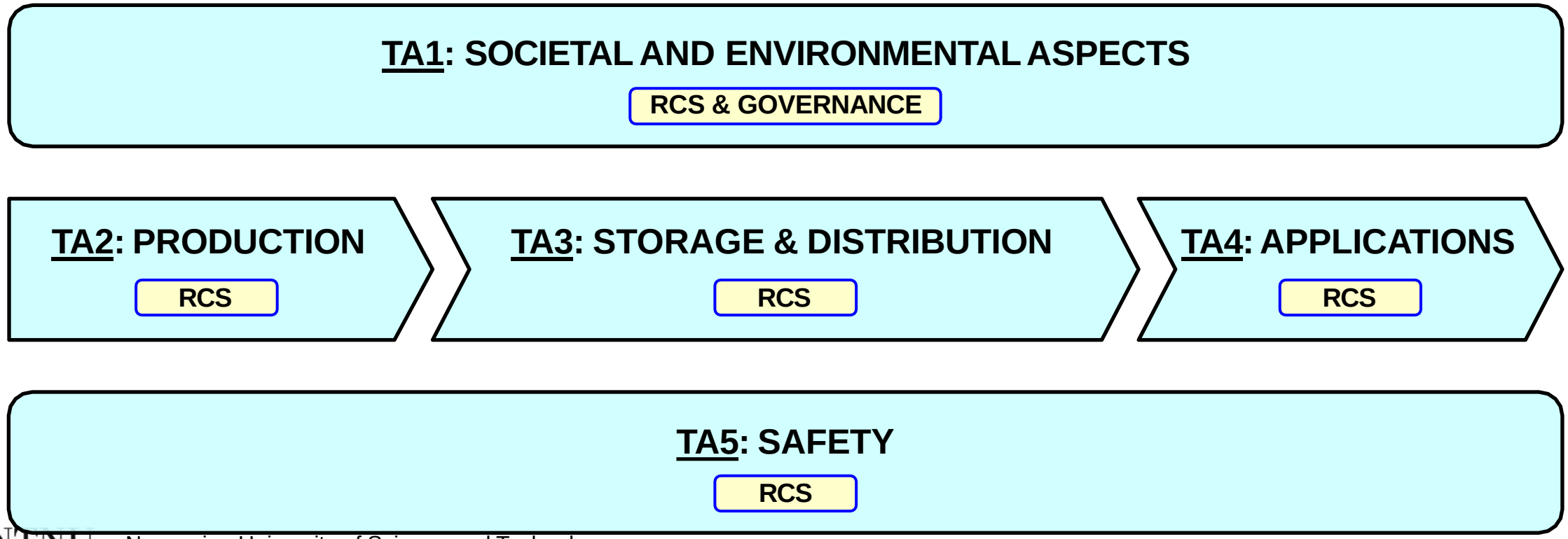
EEA-CONCERT project:

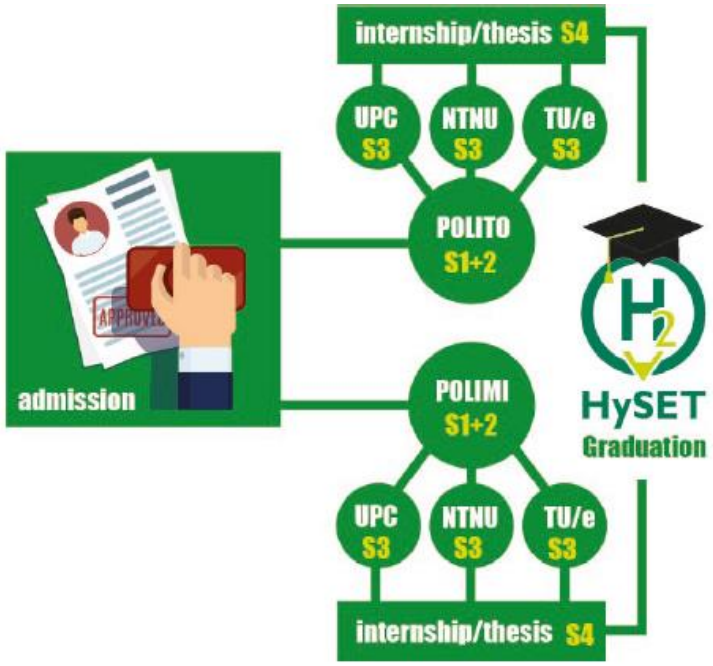
SUStainability development and cost-reduction of hybrid renewable energies powered Hydrogen stations by risk-based multidisciplinary approaches (SUSHy)



Hyschool

- **CONCEPT**: Doctoral candidates from all universities and university colleges in Norway can be admitted, provided the main topics of their PhD projects are within the range of topical areas for the research school (H_2, NH_3, …).
- **SCOPE**: The PhD projects of the admitted candidates define the scope of the activities in the research school.
- Activities addressing RCS are distributed over the five topical areas, with governance mostly in TA1.





Call: ERASMUS-EDU-2022-PEX-EMJM-MOB

(Erasmus Mundus Joint Masters)

Proposal acronym: HySET

YEAR 2 Semester 3 – NTNU Specialization Track on Hydrogen Safety

	Course name	Number Credits	Internal course ID	Compulsory / Elective
1	Safety and reliability analysis	7.5	TPK4120	Compulsory
2	Risk management in project	7.5	TPK5115	Compulsory
3	RAMS engineering and data analytics	7.5	TPK5165	Elective
4	Maintenance management	7.5	TPK4140	Elective
5	Safety and asset management, specialization course	7.5	TMR4555	Elective
6	Process operation and safety	7.5	TKP4176	Elective
7	Safe operation and maintenance	7.5	TMR4260	Elective

Thanks for listening.