



ELVHYS outcome to support education on safety of LH2 transfer technologies

ELVHYS Dissemination Conference
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Introduction

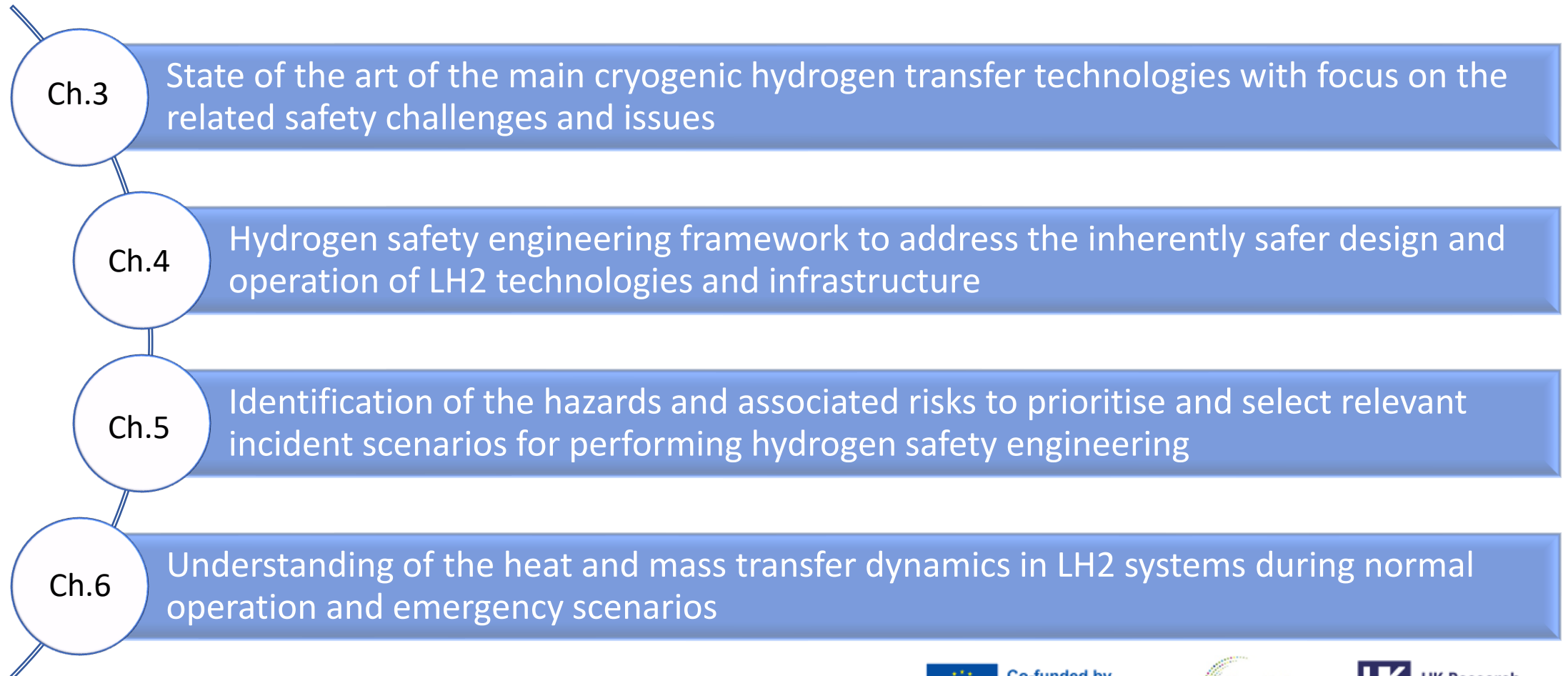
- Ensuring inherently safer design of cryogenic hydrogen applications and transfer operations requires a high level of technical competence, rigorous procedural understanding, and familiarity with the unique hazards associated with liquid hydrogen (LH2).
- These operations involve extremely low temperatures (approximately $-253\text{ }^{\circ}\text{C}$), rapid phase and mass transfer, and complex thermodynamic behaviour, all of which demand precise handling and well-informed decision-making.
- Although best practices and practical guidelines are available for storage, handling and distribution of liquid hydrogen on industrial grounds, this knowledge is not always publicly available or applicable beyond industrial applications.
- Structured training and education programmes are essential instruments and channels for equipping operators, engineers, and safety professionals with the knowledge needed to manage risks effectively and maintain operational integrity.

Research-led training materials

- The ***training materials on safety of cryogenic hydrogen transfer technologies*** aim at creating a basis for the beyond the state-of-the-art training and education programmes in academia and industry.
- ***Research-led*** training materials, built on experimentally validated findings and ELVHYS project outcomes published in peer-reviewed journal papers and conference proceedings.
- The project outcomes were complemented and further enriched with specialised advanced knowledge and experience shared by international experts and industrial practitioners during the ELVHYS workshops.
- These included training materials prepared by international experts from within and beyond the ELVHYS consortium, gathering the knowledge and insights generated by previous research projects on safety of liquid hydrogen, e.g. PRESLHY, SH2IFT, HEAVEN, FFI, etc.
- Consolidating these contributions into comprehensive training materials on safety of cryogenic hydrogen transfer technologies provides structured educational resources accessible to both academia and industry, and to a great variety of stakeholders, including emergency services.

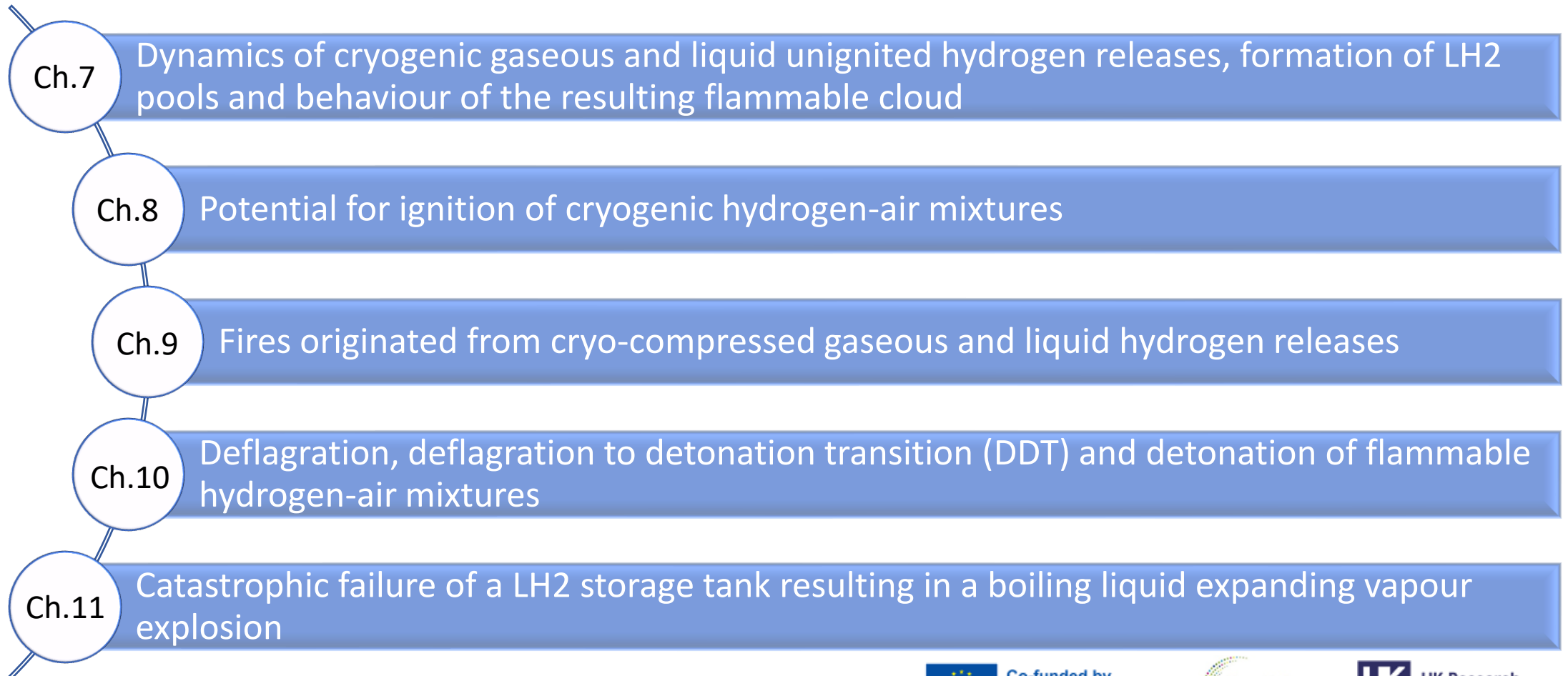
Framework of the training materials (1/3)

The training materials aim at providing overarching knowledge and understanding on the relevant safety aspects associated with cryogenic hydrogen transfer technologies and operations:



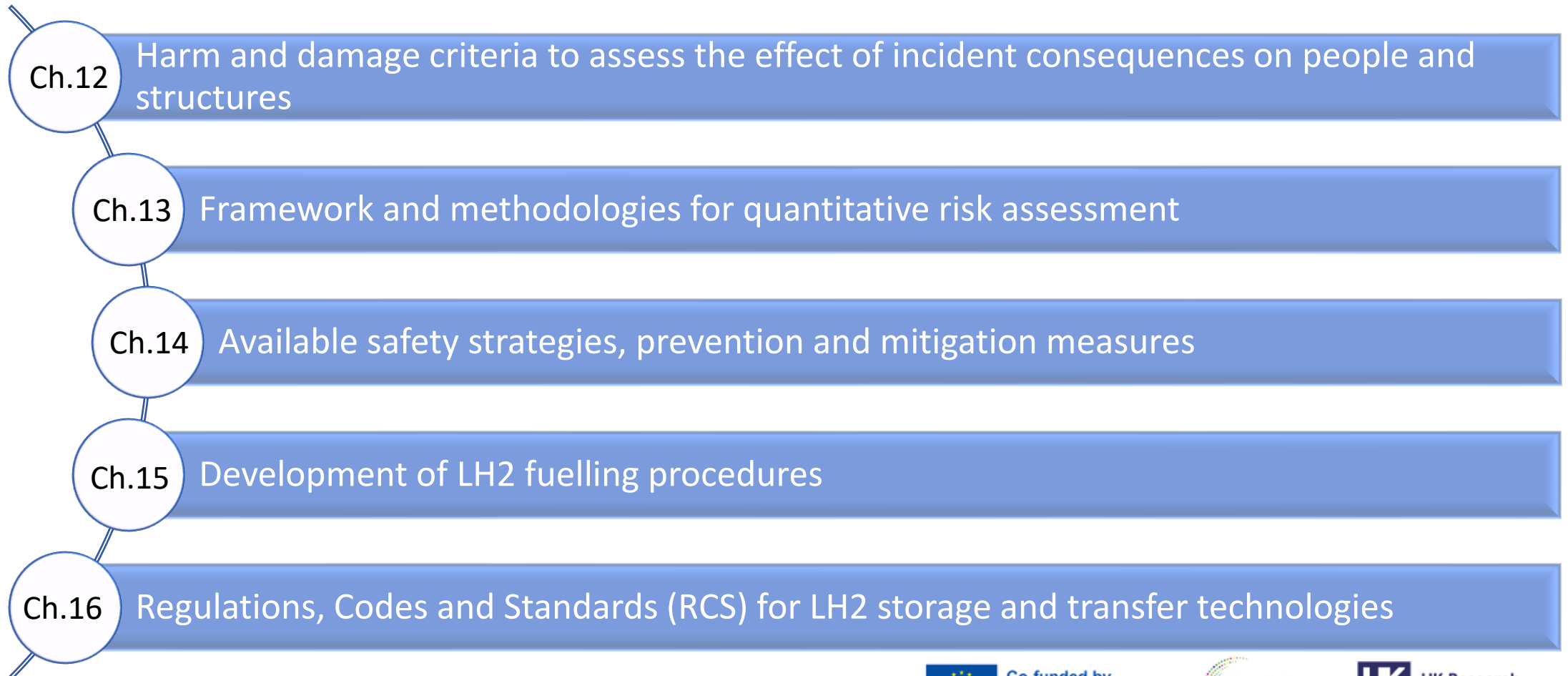
Framework of the training materials (2/3)

The training materials aim at providing overarching knowledge and understanding on the relevant safety aspects associated with cryogenic hydrogen transfer technologies and operations:



Framework of the training materials (3/3)

The training materials aim at providing overarching knowledge and understanding on the relevant safety aspects associated with cryogenic hydrogen transfer technologies and operations:



Objectives of the training materials (1/2)

Key learning objectives of the training materials on safety of cryogenic hydrogen transfer technologies (non-exhaustive list):

- **Recognise** key LH₂ transfer technologies, facilities, mobile applications and current industrial practices, enabling familiarity with the associated safety challenges, safety-relevant conditions, and key design and operating parameters.
- **Identify** hazards and associated risks for the formulation of relevant incident scenarios in cryogenic hydrogen transfer operations.
- **Understand** heat and mass transfer processes in LH₂ systems during normal and emergency conditions.
- **Explain** the safety phenomena and consequences of LH₂ transfer incidents, supported by scientific knowledge along with experimental and modelling evidence.
- **Explore** validated reduced models and validated contemporary tools, such as validated CFD and FEM models, to assess consequences and hazard distances for relevant incident scenarios involving LH₂ transfer operation.

Objectives of the training materials (2/2)

Key learning objectives of the training materials on safety of cryogenic hydrogen transfer technologies (non-exhaustive list):

- **Understand** quantitative risk assessment methodologies and their application to LH₂ transfer operations and facilities.
- **Recognise** safety strategies, prevention and mitigation measures for cryogenic hydrogen transfer operations.
- **Understand** recent advances in fuelling and bunkering modelling and procedures.
- **Become familiar with** regulations, codes, and standards relevant to liquid hydrogen applications.
- **Identify** critical safety knowledge gaps and future research needs in cryogenic hydrogen transfer.

Concluding remarks

- The training materials aim at providing expertise that supports both foundational understanding and practical application in cryogenic hydrogen transfer operations.
- The training materials offer a structured review of the relevant safety aspects of LH2 transfer technologies, highlighting the hazards and associated risks specific to LH2, and providing the scientific knowledge to assess them through complementarities of experimental, theoretical and numerical research.
- The training materials aim at being an open-access educational resource for the use of stakeholders, e.g. during training of specialised personnel, operators, engineers and safety professionals, or training of emergency responders.
- The ultimate goal is to contribute to a robust safety culture around cryogenic hydrogen technologies and support the inherently safer development of LH2 infrastructure on a large scale, by advancing competence, improving risk awareness, and fostering informed decision-making in a rapidly evolving technological field.



Thank you for your attention

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