Model evaluation protocol for CFD analysis of hydrogen safety issues

Computational Fluid Dynamics (CFD) for hydrogen safety analysis

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EUROPEAN PARTNERSHIP

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Context

CFD is increasingly used to perform safety analysis of potential accident scenarios:

- ✓ production
- ✓ storage
- ✓ distribution of hydrogen
- ✓ its use in fuel cells

- ✓ CFD is a powerful numerical tool
- ✓ … but it also requires a high level of competence and knowledge

- ➢ capability of the CFD models to accurately describe the relevant physical phenomena
- ➢ capability of the CFD users to follow the correct modelling strategy

The reliability/accuracy of the CFD results remains a significant concern

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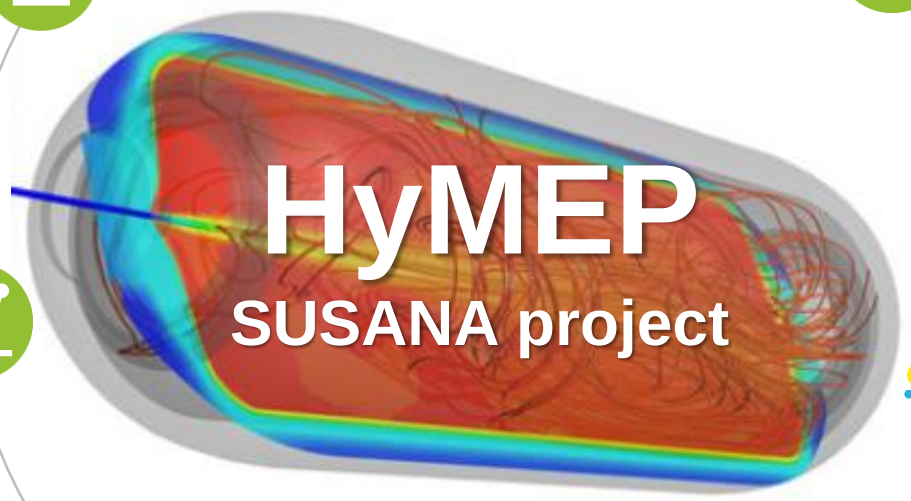
Model Evaluation Protocol - HyMEP

Reference document for all those groups that develop, apply and use CFD models in the area of FCH technologies and beyond



All aspects of hydrogen safety phenomena have been considered:

- ✓ Release
- ✓ mixing and dispersion of gaseous and liquid hydrogen
- ✓ Ignition
- ✓ Fire
- ✓ deflagration, deflagration-to-detonation transition and detonation.

- ✓ To assess the user capability of correctly using CFD codes
- ✓ To help the user to evaluate the accuracy and limitations of the CFD models themselves.

Applicable to other safety-related phenomena:

- ✓ tank filling
- ✓ consequences of catastrophic rupture of a high-pressure hydrogen tank in a fire
- ✓ etc.

- ✓ CFD developers (academia and research institutes)
- ✓ users (such as industry and engineering consultancy companies)
- ✓ regulatory/certifying

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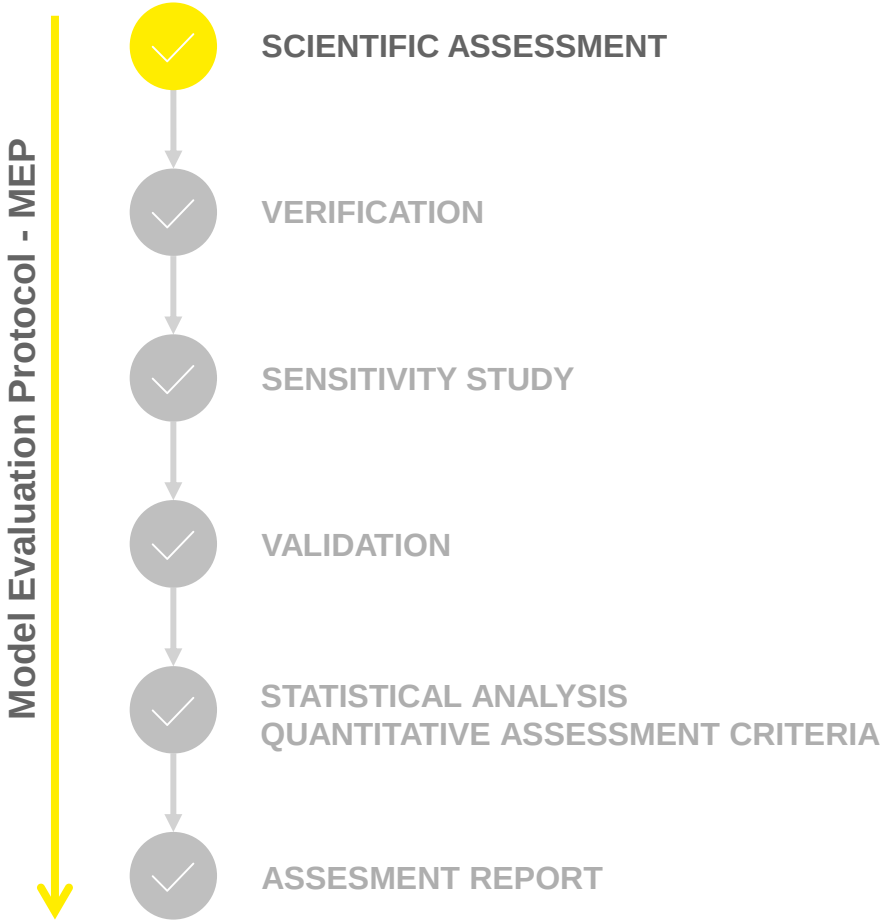
HyMEP Structure



Scientific Assessment

- ✓ Initial critical analysis of the model based on available knowledge in the field
- ✓ Critical review: physical, mathematical and numerical model basis
- ✓ Identify the known and/or expected weakness and strengths from available literature and knowledge
- ✓ Scientific content: Assumptions/simplifications/applicability range

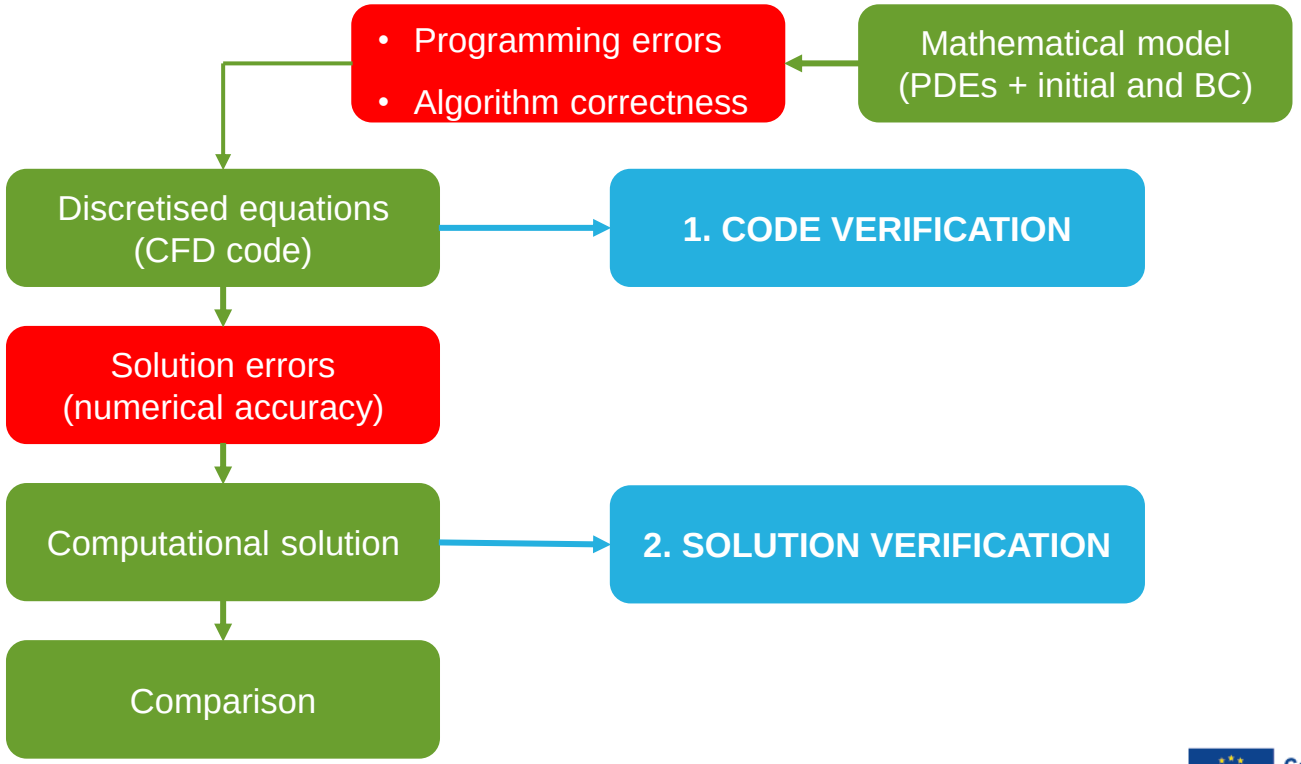
HyMEP Structure

Model Evaluation Protocol - MEP

- SCIENTIFIC ASSESSMENT
- **VERIFICATION**
- SENSITIVITY STUDY
- VALIDATION
- STATISTICAL ANALYSIS
  QUANTITATIVE ASSESSMENT CRITERIA
- ASSESEMENT REPORT

Verification

✓ Verification is used to ensure that a mathematical model has been correctly implemented in software i.e. the equations are correctly solved



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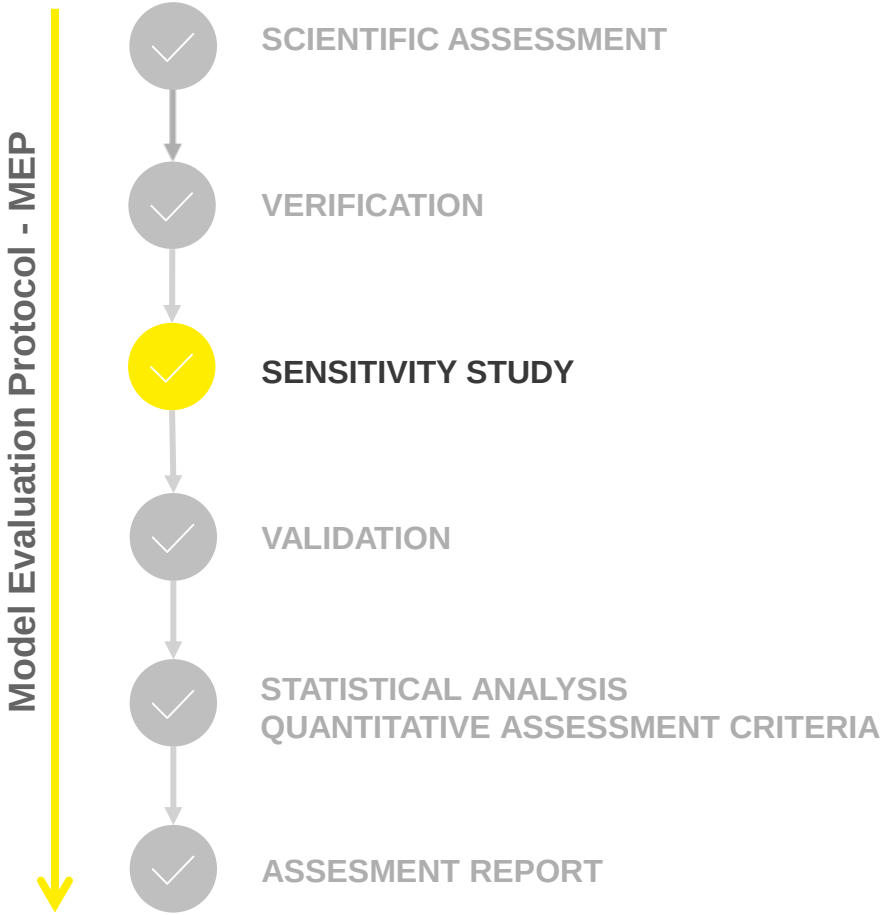
HyMEP Structure



Sensitivity Study

✓ The user should ensure that the simulation results are unaffected by numerical errors:

- Grid independency
- Time-step
- CFL sensitivity
- Numerical scheme
- Boundary conditions
- Domain size

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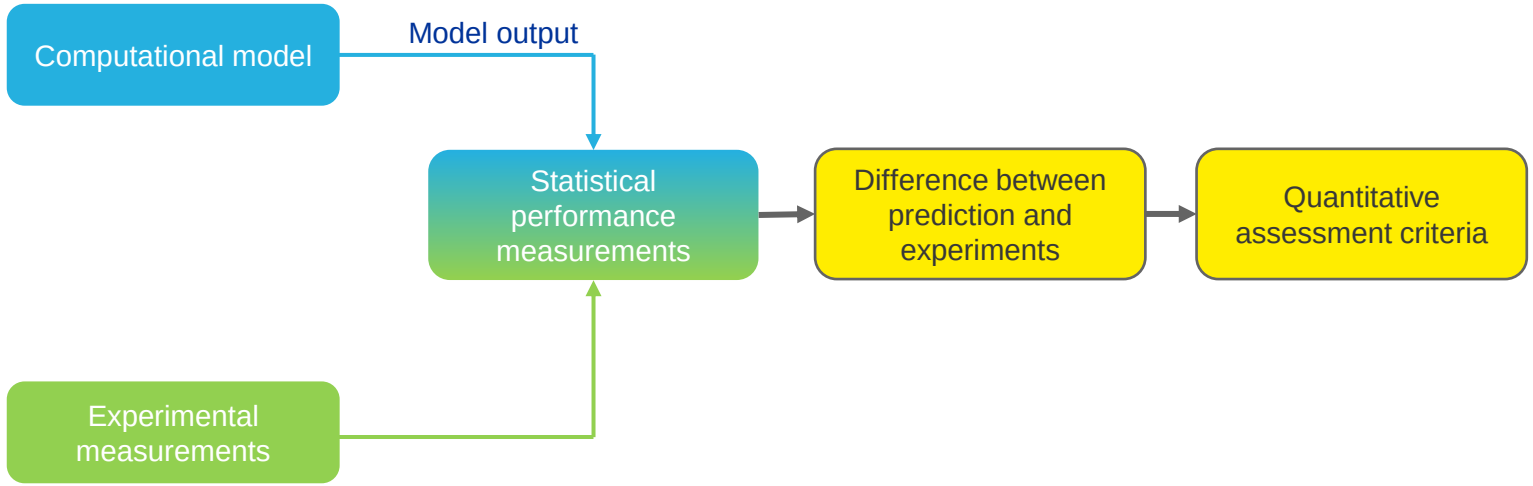
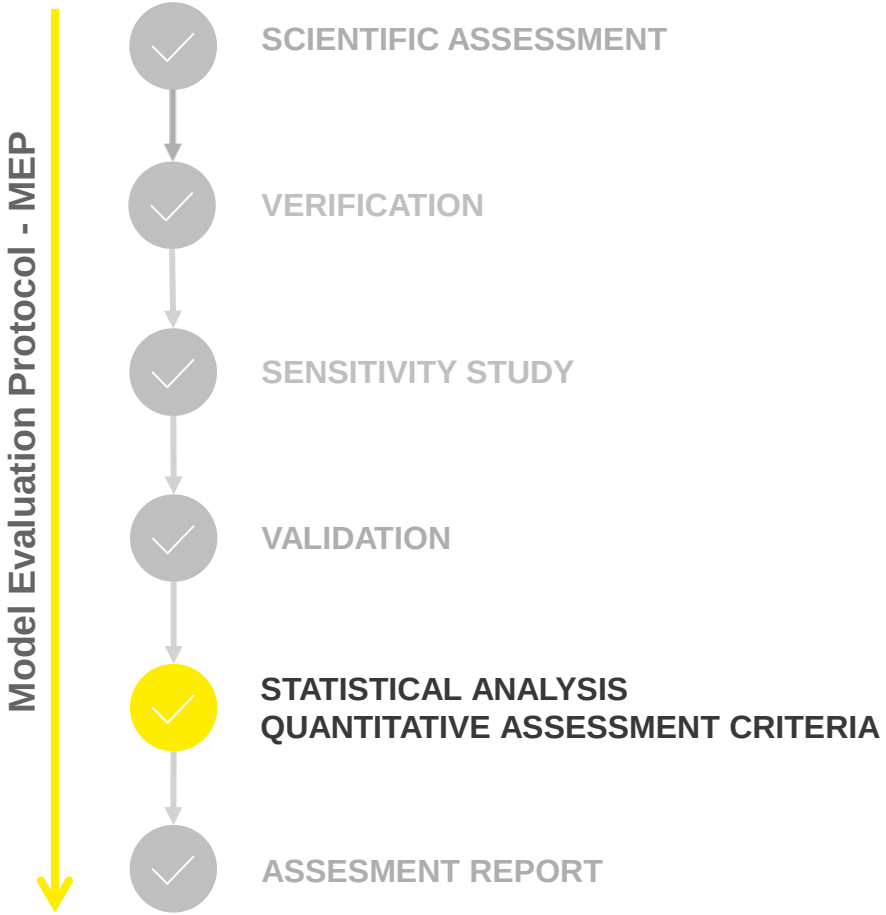
Validation

- ✓ Model outputs are compared with measurements of physical parameters to demonstrate that the model captures “real world” behavior across its intended range of applicability.
- ✓ Quantitative comparison of experimental observations vs. model predictions



HyMEP Structure



Quantitative Assessment Criteria

- ✓ Identification of target variables for each phenomenon under consideration
- ✓ Statistical analysis:
  - Performance parameters
  - Methodology
  - Quantitative criteria
  - Sensitivity and uncertainty

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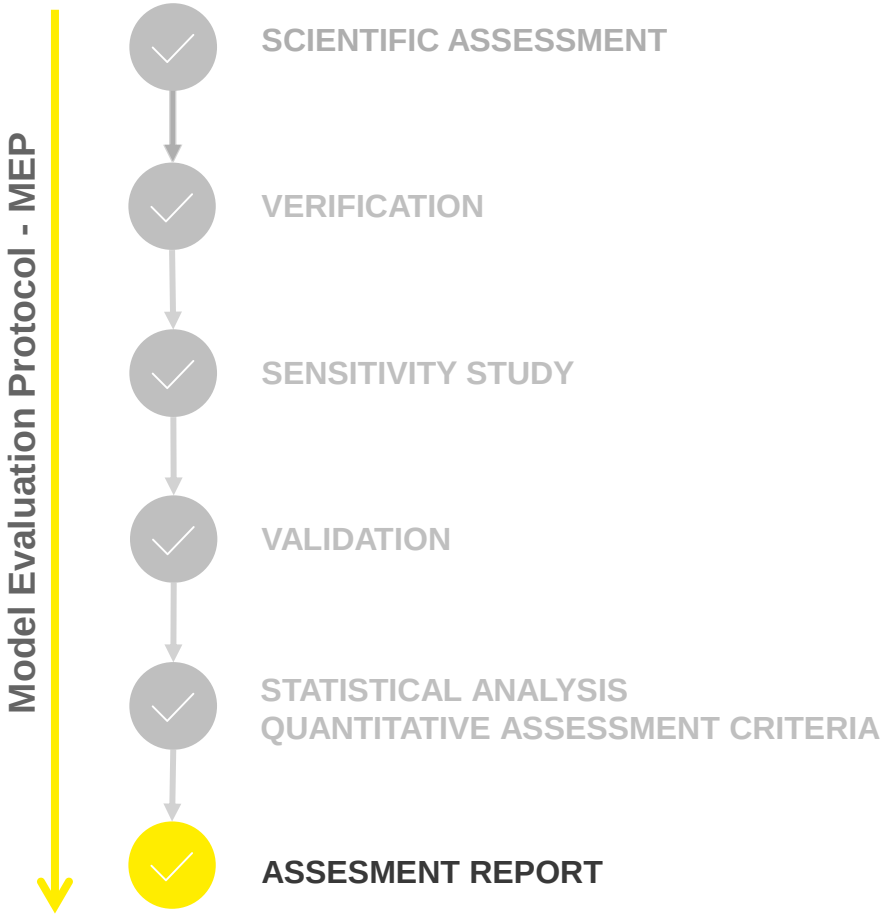
HyMEP Structure



Assessment Report

- ✓ Analysis of information supplied by model developer/expert user.
- ✓ Detailed model description
- ✓ Scientific assessment
- ✓ Verification and validation
- ✓ Sensitivity study
- ✓ Statistical analysis
- ✓ Conclusions

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Keep in touch/Thank you

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For further information
https://www.clean-hydrogen.europa.eu/

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