Statistics, lessons learnt and recommendations from the analysis of HIAD 2.0 database

Jennifer X. WEN
Head of Warwick FIRE, University of Warwick
Leader of Task Force TF3
European Hydrogen Safety Panel (EHSP)

Contributors from EHSP: Ernie A. Reinecke, Pratap Sathiah, Etienne Studer, Elena Vyazmina, Marta Marono
Contributor from JRC: Pietro Moretto

21-23 September 2021

Outline

European Hydrogen Safety Panel (EHSP)

- Background
- Overview of the analysis approach
- Statistics
- Lessons learnt
- Recommendations
- Access to HIAD 2.0 and reporting of new events

Background

European Hydrogen Safety Panel (EHSP)

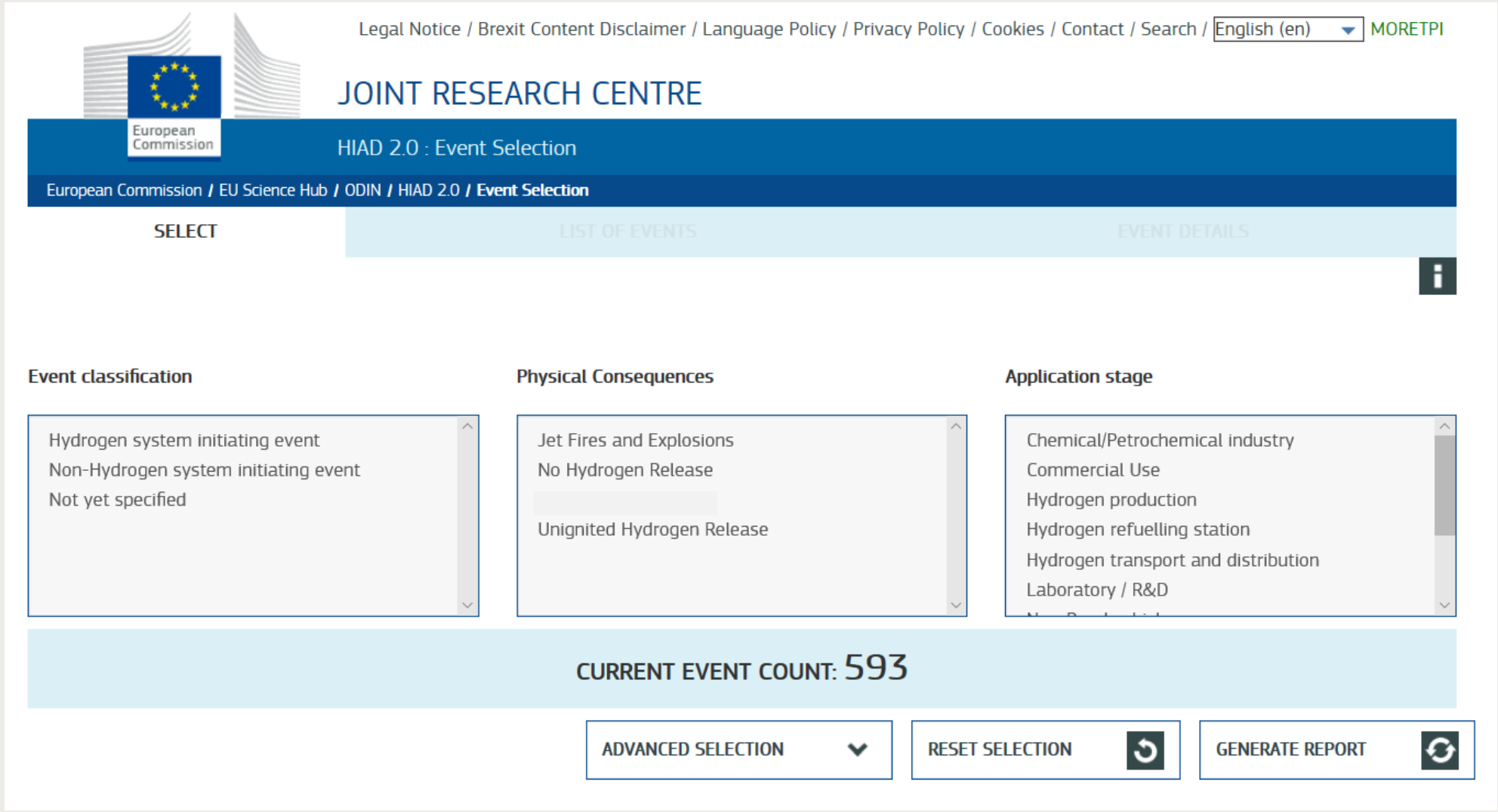
- The Hydrogen Incidents and Accidents Database (HIAD) was firstly developed within the HySAFE Network of Excellence by the Joint Research Centre of the European Commission (JRC) .
- Updated by JRC as HIAD 2.0 in 2016.
- Since its launch in 2017, the EHSP has been working closely with JRC to enlarge and improve HIAD 2.0.

Sources of HIAD 2.0:

- public, from scientific literatures, news.
- Other public not hydrogen-specific databases such as French ARIA, European (SEVESO) eMARS, US CSB, NTSB ,OHSA national nuclear authorities, etc.

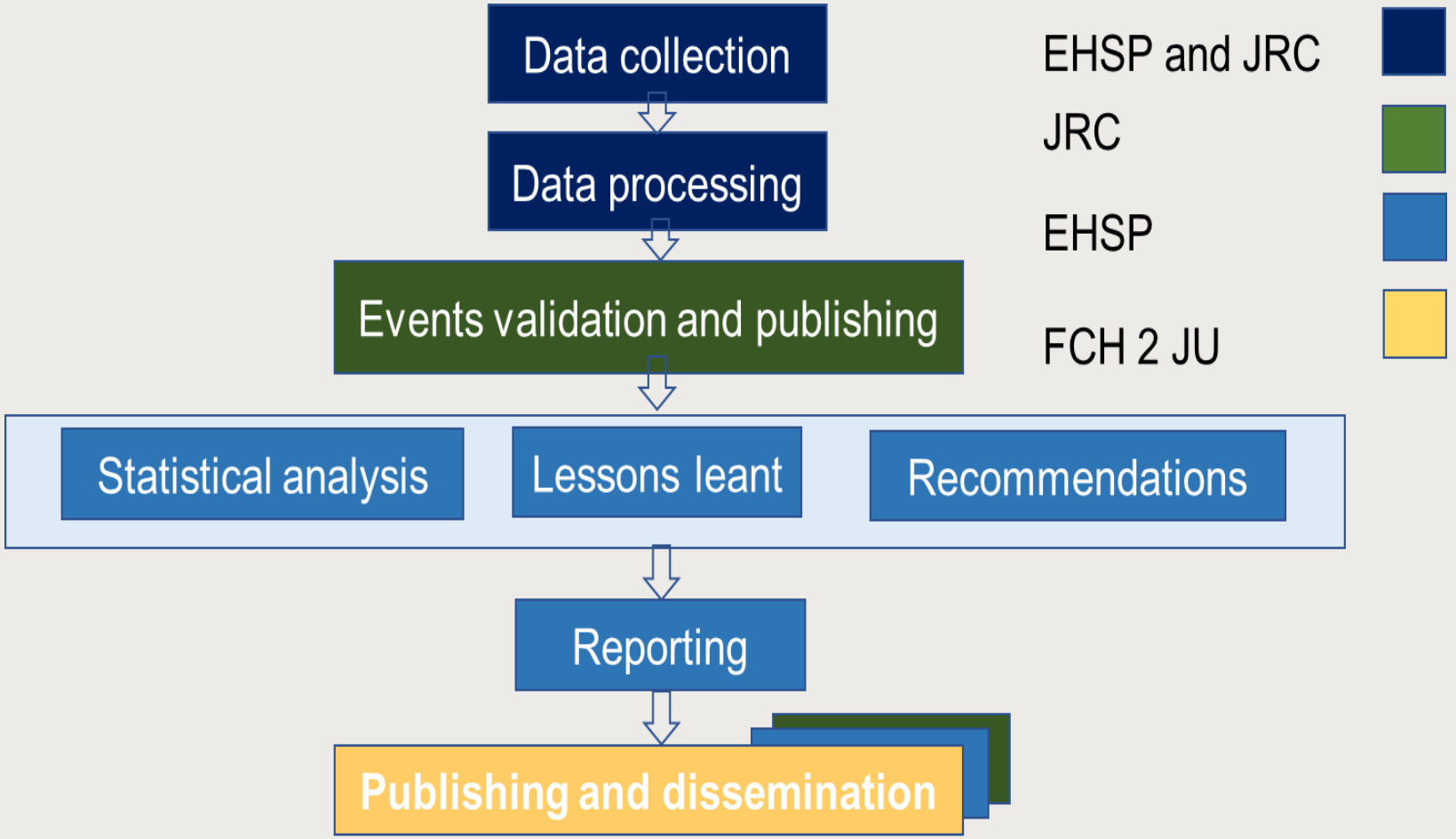
HAID 2.0 frontpage

European Hydrogen Safety Panel (EHSP)



Overview of the data collection and assessment process

European Hydrogen Safety Panel (EHSP)



The methodology

European Hydrogen Safety Panel (EHSP)

- **Severity** (based on European scale of industrial accidents *https://www.aria.developpement-durable.gouv.fr/wp-content/uploads/2014/08/European-scale-of-incidents.pdf*)

  Quantities of hydrogen involved (Seveso threshold or the amount of hydrogen involved)

  Human consequences (fatalities, injured with hospitalisation, slightly injured)

  Economic consequences (property damage or economic cost)

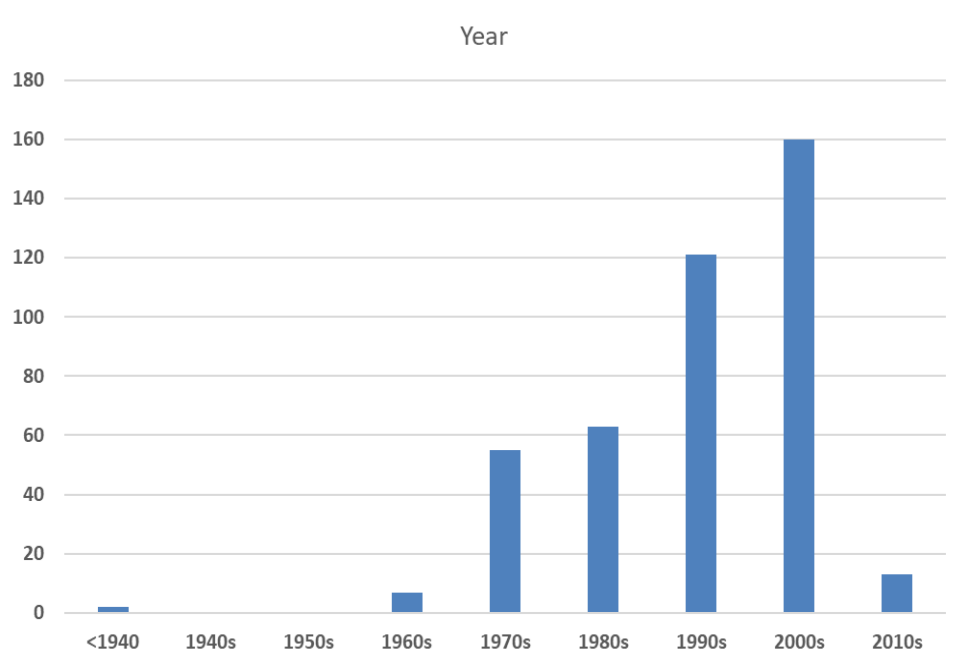
- **Nature** of event (explosion, fire, unignited release, near miss)
- **Cause** (system design error, material/manufacturing error, installation error, job factors, Individual/human factors, organization and management factors)
- **Recommendations** (based on EHSP safety principles *https://www.fch.europa.eu/sites/default/files/Safety_Planning_for_Hydrogen_and_Fuel_Cell_Projects_Release1p31_20190705.pdf*)

Results from the statistics analysis (1)

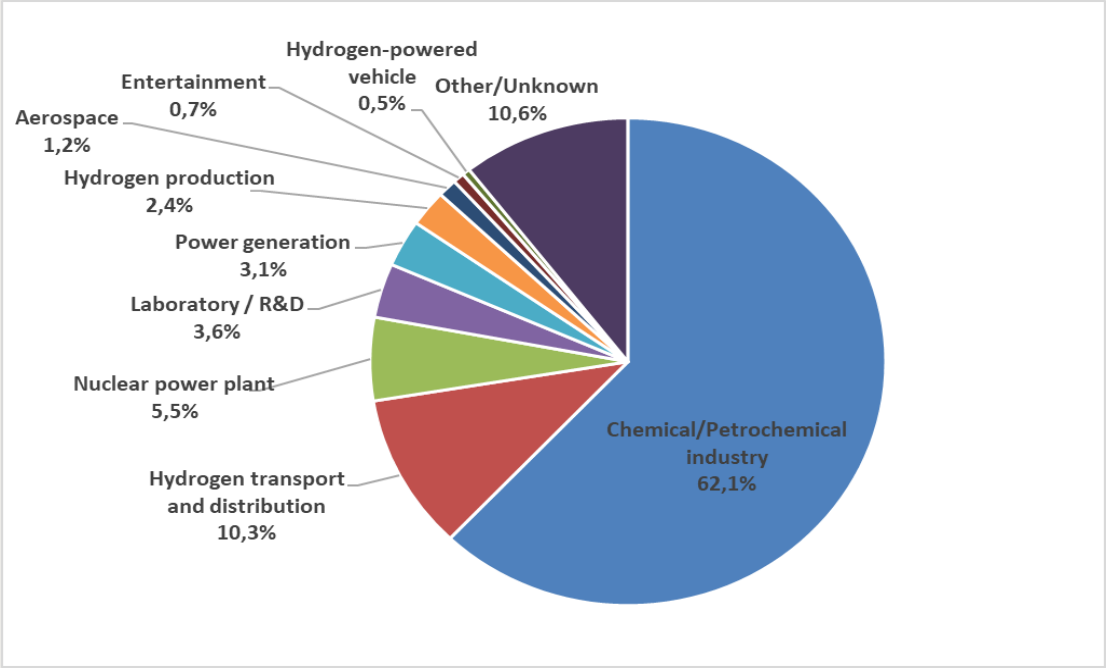
European Hydrogen Safety Panel (EHSP)

The current analysis is based on the 485 incidents available in the database in July 2020. Of which, 426 events were statistically relevant.

Years



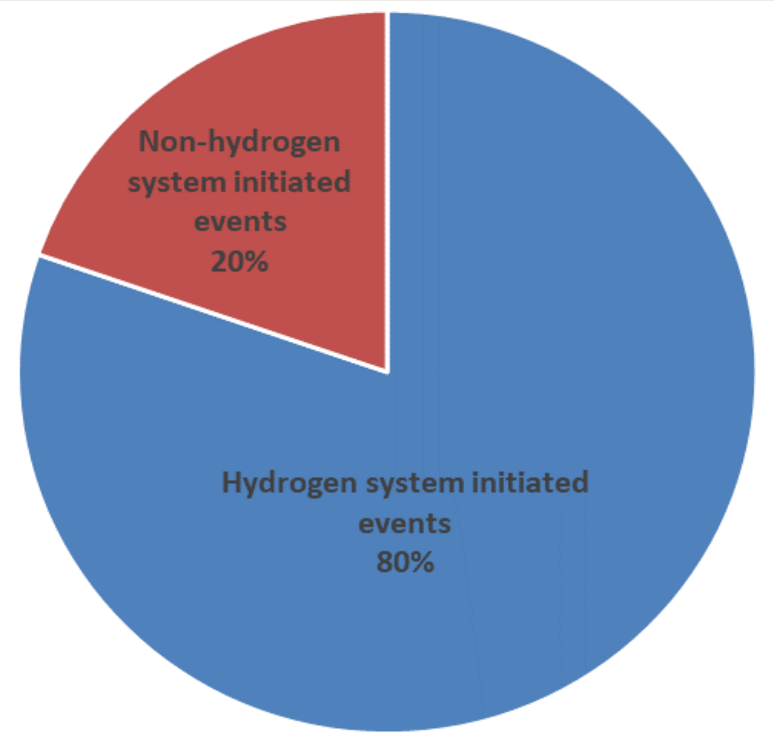
Industrial sectors



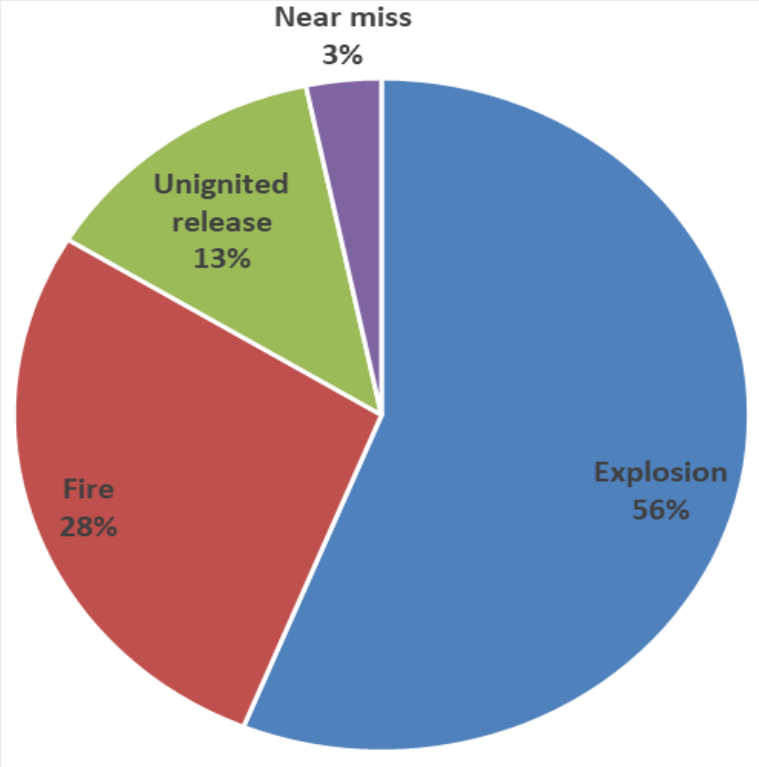
Results from the statistics analysis (2)

European Hydrogen Safety Panel (EHSP)

Hydrogen systems/non-hydrogen systems



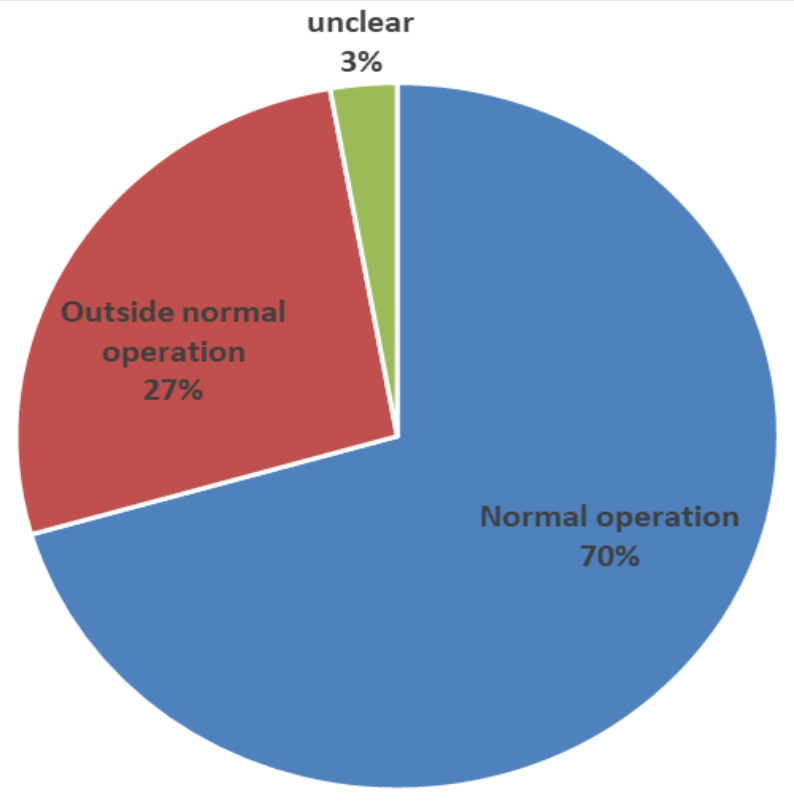
Physical consequences



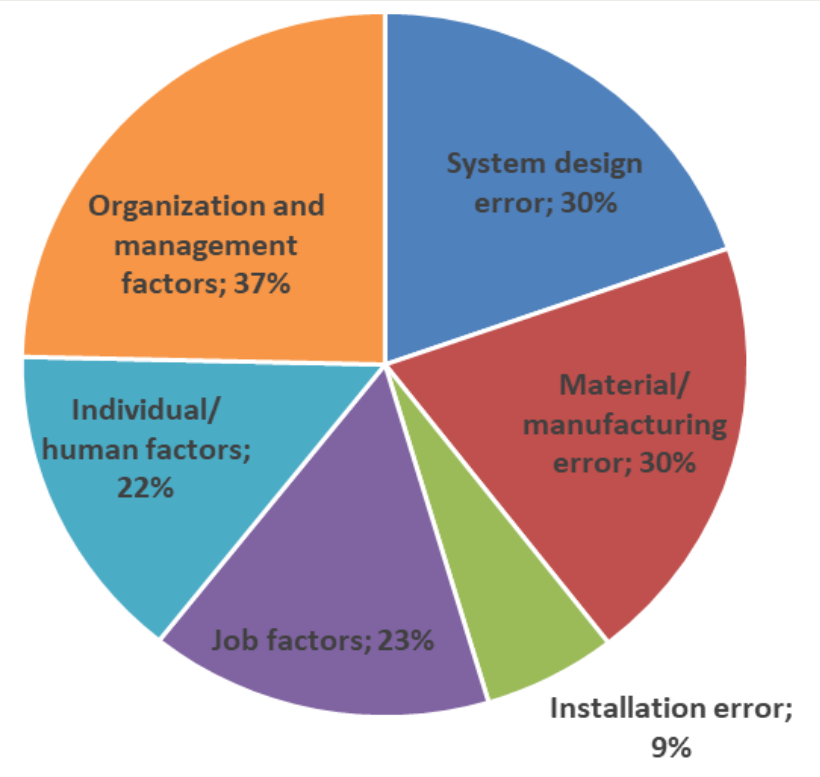
Results from the statistics analysis (3)

European Hydrogen Safety Panel (EHSP)

Operational mode



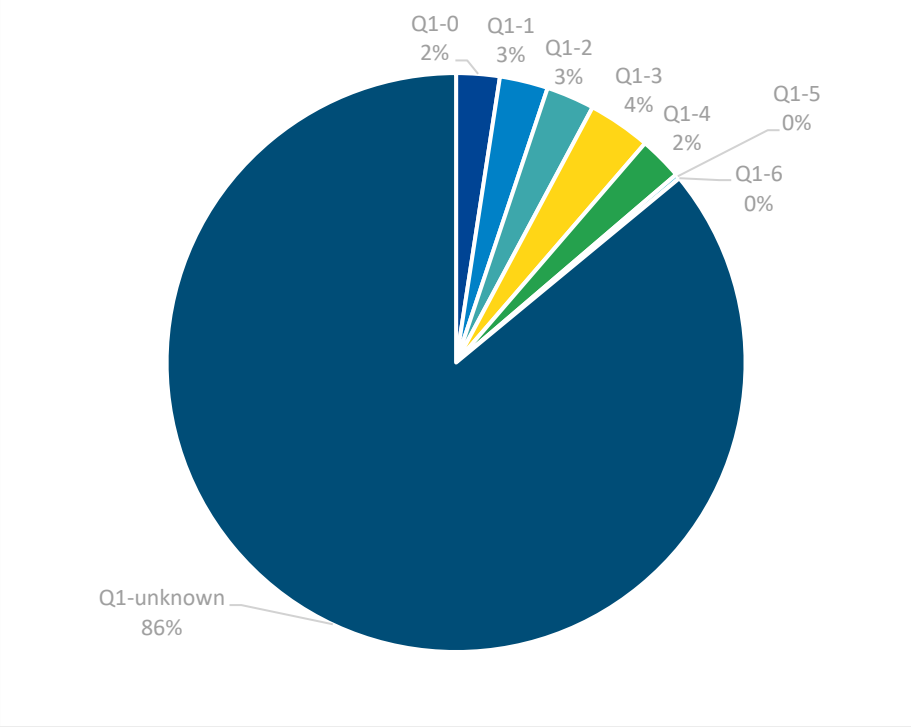
Causes (multiple entries per incident possible)



Results from the statistics analysis (4)

European Hydrogen Safety Panel (EHSP)

Percentage of events classified by quantity of hydrogen

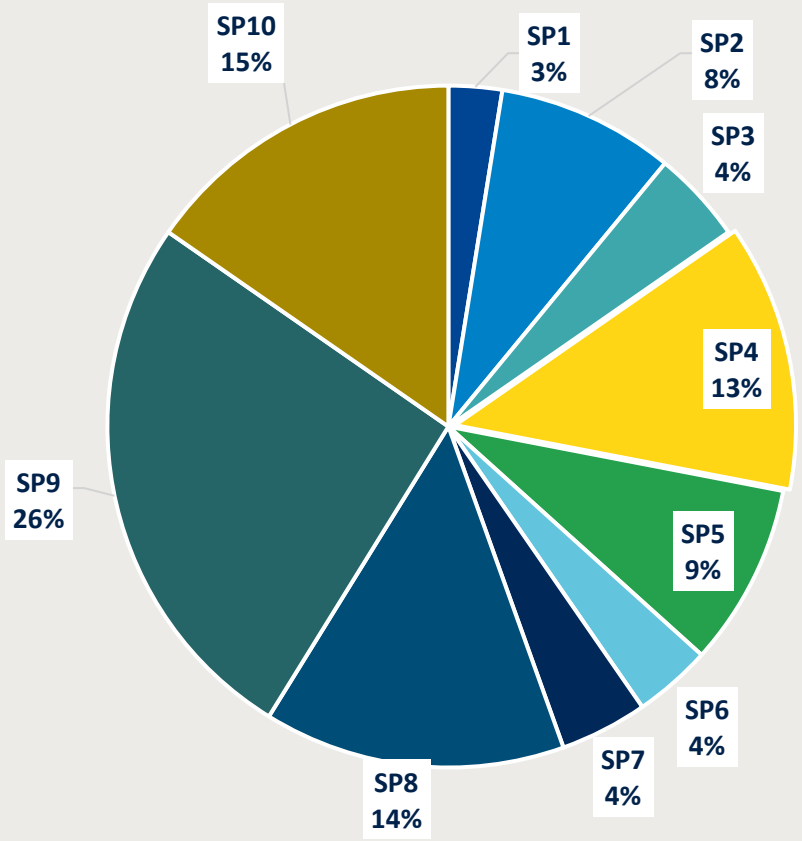


The severity of the incidents has been assessed according to the European scale of industrial accidents which is based on the Seveso directive: *https://www.aria.developpement-durable.gouv.fr/wp-content/uploads/2014/08/European-scale-of-accidents.pdf*

Quantities of dangerous substances		1	2	3	4	5	6
Q1	Quantity Q of substance actually lost or released in relation to the "Seveso" threshold *	Q < 0.1%	0.1% ≤ Q < 1%	1% ≤ Q < 10%	10% ≤ Q < 100%	1 to 10 times the threshold	≥ 10 times the threshold

Statistics related to EHSP identified safety principles (SP#)

European Hydrogen Safety Panel (EHSP)



Number	Safety Principle *https://www.fch.europa.eu/sites/default/files/Safety_Planning_for_Hydrogen_and_Fuel_Cell_Projects_Release1p31_20190705.pdf*
SP1	Limit hydrogen inventories, especially indoors, to what is strictly necessary.
SP2	Avoid or limit formation of flammable mixture, by applying appropriate ventilation systems, for instance.
SP3	Carry out ATEX zoning analysis.
SP4	Combine hydrogen leak or fire detection and countermeasures.
SP5	Avoid ignition sources using proper materials or installations in the different ATEX zones, remove electrical systems or provide electrical grounding, etc.
SP6	Avoid congestion, reduce turbulence promoting flow obstacles (volumetric blockage ratio) in respective ATEX zones.
SP7	Avoid confinement. Place storage in the free, or use large openings which are also supporting natural ventilation.
SP8	Provide efficient passive barriers in case of active barriers deactivation by whatever reason.
SP9	Train and educate staff in hydrogen safety.
SP10	Report near misses, incidents and accidents to suitable databases and include lessons learned in your safety plan.

Not including the newly added SP11 “ensure that the design of hydrogen system and material selection are compatible with hydrogen services”

Lessons learnt – approach of the analysis in a nut shell

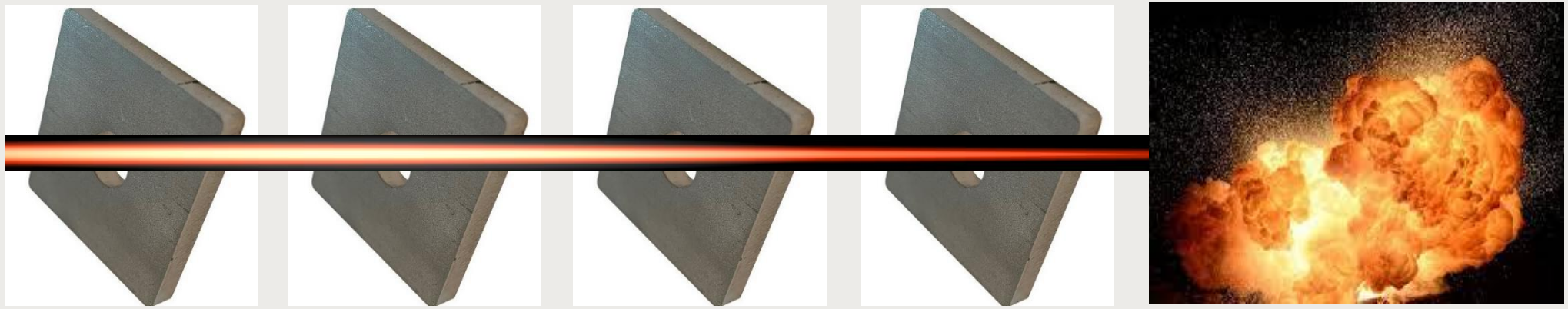
European Hydrogen Safety Panel (EHSP)

Main categories	System design	System manufacturing, installation and modification	Operator errors			First responders
			Job factors	Individual/ human factors	Organization& management factors	
Sub-categories	Design related	Material compatibility	Maintenance and inspection	Bypassing key interventions	Out of date inspection plan	Insight of H_2 safety and accident scenarios
	Corrosion related	Venting system	Safety device during maintenance	Inadequate training of H_2 truck drivers	Inspection of safety equipment	Delay in limit inventories
	Fatigue	Weak points	Safety practice and procedures	Monitoring pressure of the filter	Procedures for plant modification	Training
	Pressure relief valve	System installation	Lack of clear instructions	Irregular purging of the system	Safety supervision during repairing	Emergency response inhibited by poor drainage
	Equipment factor		Chemical componds prone to H_2 generation	Verification of design and operation conditions	Procedures for fast isolation of release sources	Lack of sufficient evidence gathering
	H_2 generation due to malfunction		Insufficient check after repair	Emergency procedure not followed	Guidance about lifetime of critical components	Extinguishing fire before H_2 release stopping
	H_2 accumulation		Insufficient purging before re-using	Guidance to prevent unwanted H_2 generation	Explosivity control before maintenance	Efficient safety crew
	Venting			Handover between shift and day staff	Distinction between emergency and operating alarms	
	2nd order redundancy on critical systems			Mindful of volatile hydrocarbon pressure in tanks		
				workplace safety violation		

Lessons learnt in relation to cascading effects

European Hydrogen Safety Panel (EHSP)

Cascading effects of minor events could result in extremely serious consequences



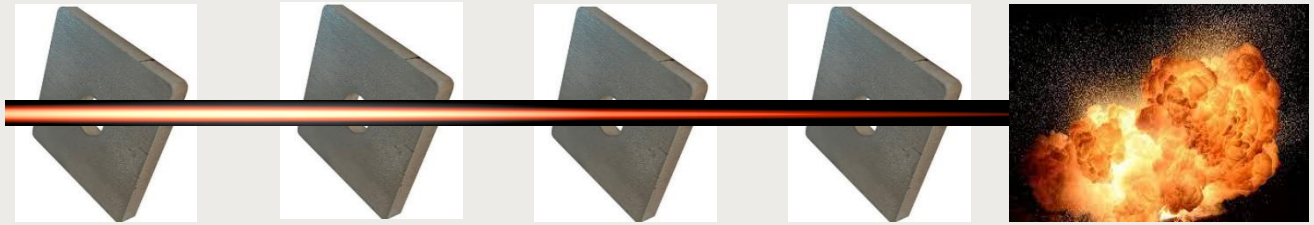
Example of recent incident ID477: An explosion of hydrogen storage tanks of a small fuel-cell power system in Gangneung (South Korea) in 2019

European Hydrogen Safety Panel (EHSP)

Prosecutor's report on Gangeung Hydrogen Tank Explosion Accident (adapted from the English translation by INERIS)

Contributing factors:

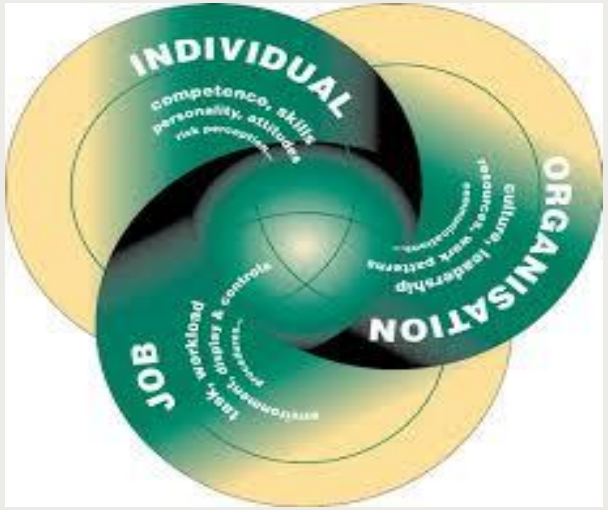
- Oxygen removing component omitted in the system …
- Buffer tank static spark remover was omitted during construction…
- Operator made fault by running water electrolysis system lower than operation power level, which induced increase of O_2 concentration…
- The O_2 concentration was detected as > 3%, which required O_2 detector and remover. However, the operator ignored this issue and continued operation to reach 1000 hours of required experiment validation time.
- Safety management team did not follow safety regulation to daily test hydrogen quality.



Lessons learnt related to job factor

European Hydrogen Safety Panel (EHSP)

- Lack of regular maintenance or inspection, special attention for safety devices during maintenance
- Reoperation after repair
- Individual/human factors, lack of clear instructions
- Reusing tanks or pipes previously containing flammable liquid or gas without thorough purging.



https://www.ciobacademy.org/wp-content/uploads/2017/07/Root-Cause-Analysis-2018.pdf

Example of recent incident: Hydrogen fuelling station explodes in Norway

European Hydrogen Safety Panel (EHSP)

Nel investigation into explosion at Kjørbo hydrogen station. Fuel Cells Bulletin 2019; 2019(7): 7

- The incident was attributed to an **assembly error** of a specific plug in a high-pressure hydrogen storage tank.
- It started with a **hydrogen leak** from a plug in one of the tanks in the high-pressure storage unit.
- This leak created a **mixture of hydrogen and air** that ignited and created a pressure wave.
- The specific source of ignition is yet to be identified.
- The low-pressure steel and composite storage units were neither the source of the leak, nor the ignition source, and no tanks ruptured in the incident.

https://www.petrolplaza.com/news/22174

Structure of recommendations at a glance

European Hydrogen Safety Panel (EHSP)

<table>
<tr><td rowspan="8">Recommendations</td><td>Operational mode</td><td colspan="2"></td></tr>
<tr><td rowspan="6">Industrial sectors</td><td rowspan="5">Hydrogen energy</td><td>H_2 transport and distribution</td></tr>
<tr><td>H_2 powered vehicle</td></tr>
<tr><td>Laboratory / R&D</td></tr>
<tr><td>Power generation</td></tr>
<tr><td>Entertainmen</td></tr>
<tr><td rowspan="3">Other industrial sectors</td><td>Nuclear</td></tr>
<tr><td>Aerospace</td></tr>
<tr><td>Chemical/petrochemical sector</td></tr>
<tr><td>Other sectors</td><td colspan="2" rowspan="2"></td></tr>
<tr><td>Human erros</td></tr>
</table>

Recommendations for different operational modes

European Hydrogen Safety Panel (EHSP)

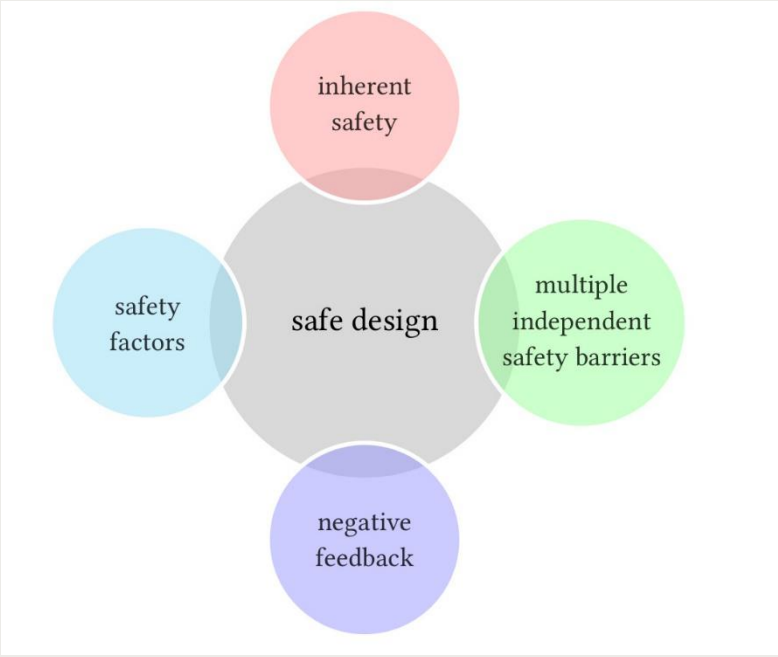
- Adequate training of personnel is key (SP9) - training of new personnel as well as periodic updated training of existing personnel.
- Both passive and active safety measures should be appropriately considered (SP7, SP8).
- Leak detection (SP4) and ATEX zoning (SP3, SP5) should be applied to improve safety.
- Regular inspection and maintenance.
- When operational/equipment changes are made, the maintenance/inspection procedures should also be updated accordingly.

https://eta-safety.lbl.gov/content/integrated-safety-management-ism

Recommendations for hydrogen energy applications – system design

European Hydrogen Safety Panel (EHSP)

- Perform Process Hazard Analysis for any new/updated installations (SP1-10);
- Use materials which are compatible with hydrogen services. In some incidents, such problem resulted in the need to change standards and codes for pressure vessels;
- Install adequate leak detection and mitigation barriers (SP4, SP8) for critical systems.

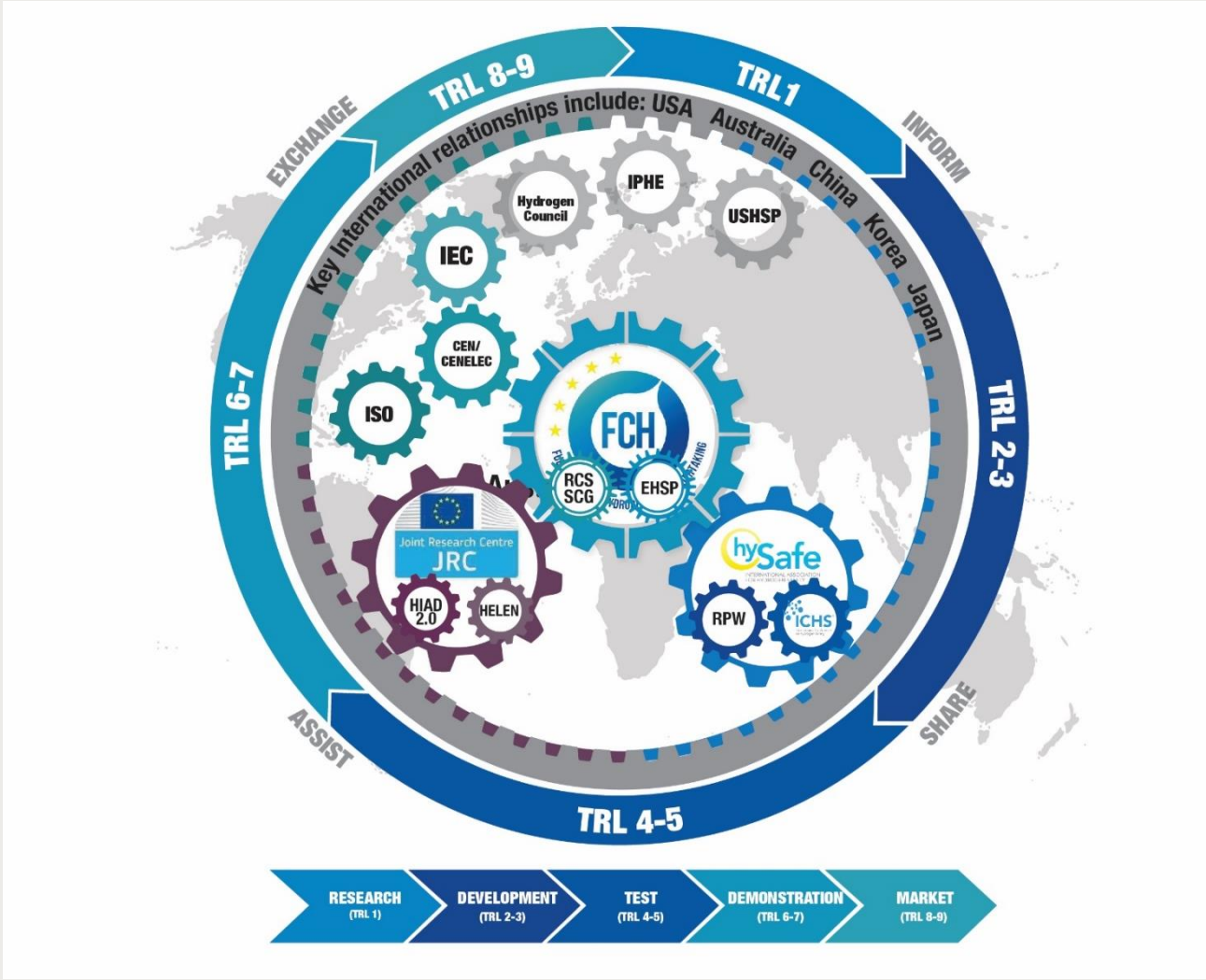


https://risk-engineering.org/safe-design/

Concluding remarks

European Hydrogen Safety Panel (EHSP)

- HIAD is being continuously enlarged and enhanced by EHSP and JRC
- Currently 593 events have been validated through quality checking
- In 2020, EHSP analysed 485 incidents which were in the database then. The detailed report on the statistics, lessons learnt and recommendations will be published on the FCH 2 JU web site *https://www.fch.europa.eu/page/european-hydrogen-safety-panel*



Access to HIAD 2.0 and reporting of new events

European Hydrogen Safety Panel (EHSP)

- While HIAD 2.0 database is offline due to maintenance, those who need to access the information should contact pietro.moretto@ec.europa.eu
- Potential event providers can report to HIAD through an ad-hoc EUSurvey: https://ec.europa.eu/eusurvey/runner/HIAD_v2_event_report
- Event providers using EUSurvey should notify pietro.moretto@ec.europa.eu as the system does not send him automatic notification of a new entry.