FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

Set of Prototypical Hazards / Risk Evaluation and Acceptance criteria - Overview

Workshop on Safety of Electrolysis

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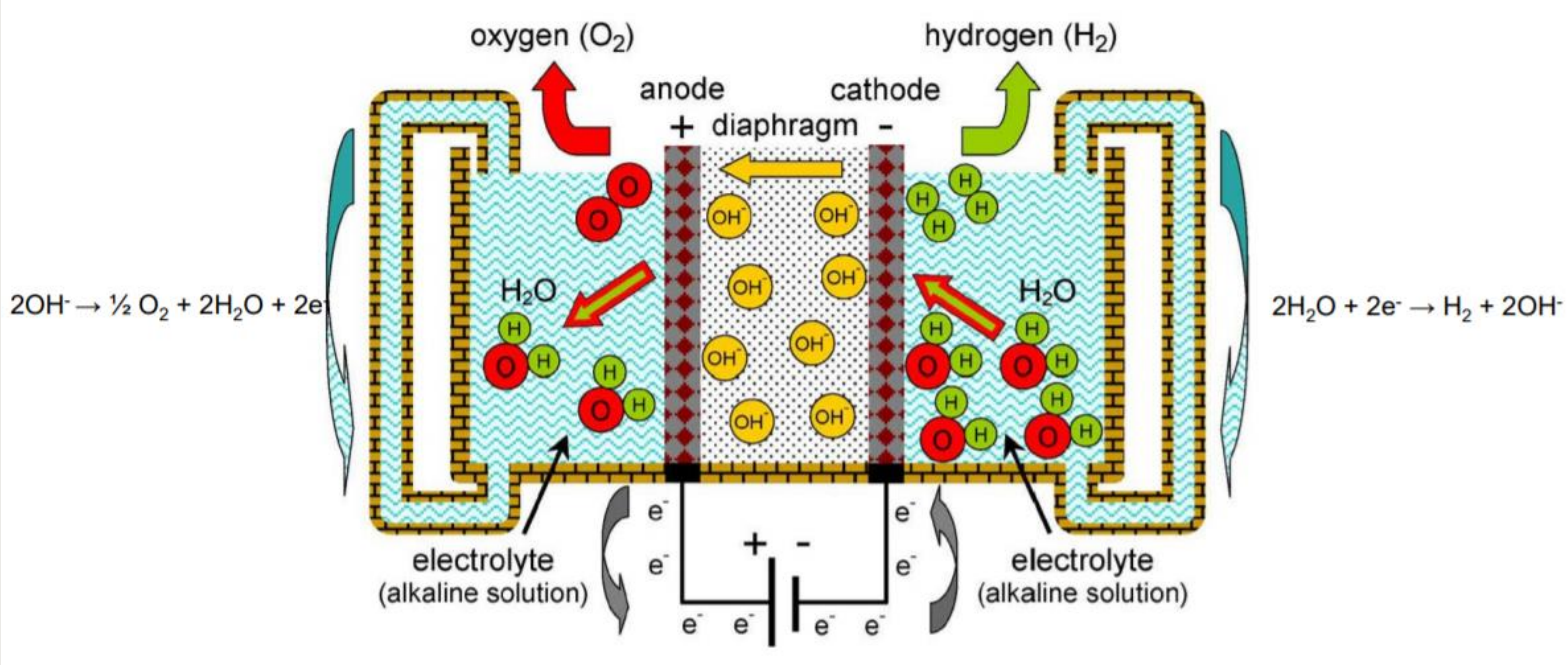
18 November 2020

Electrolysis

- promising option for hydrogen production from renewable resources.
- process of using electricity to split water into hydrogen and oxygen.
- It consist of an anode and a cathode separated by an electrolyte.
- Different electrolysers function in slightly different ways,. For example
- Polymer electrolyte membrane electrolysers
- Alkaline electrolysers
- Solid oxide electrolysers



Schematic of PEM electrolysers

Set of Prototypical Hazards - 1

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Hazards

Potential source of harm (a chemical or physical condition that has the potential for causing damage to people, property/asset and the environment).

Hydrogen (stored and high pressure hydrogen)

- Hydrogen is a gas with low molecular weight (2 gm/mole)
- It has a wide range of flammability limit (4-76 %) in air and (3.96-96 %) in pure oxygen
- low ignition energy (0.02 mJ) and high laminar flame speed (2.37 m/s and 10.59 m/s) when hydrogen is mixed with air/oxygen to form stoichiometric mixture.
- A hydrogen flame is almost invisible.
- Emits less radiation than a hydrocarbon flame and burns without producing smoke.

Oxygen

- oxygen is not flammable gas,
- enhanced/reduced oxygen level (>25 % and less than 19.5 %) in the air can lead to breathing difficulties and even fatality.
- there is an enhanced risk of fire at high oxygen concentration

Set of Prototypical Hazards - 2

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High Voltage Electricity

- Risk of Electrocution and possible ignition sources for flammable hydrogen-air and oxygen mixtures.

Electrolyte (e.g. KOH)

- Release of caustic electrolyte (hot or highly caustic electrolyte)
- Eye damage and skin burn/harm to the people
- Impact to the material

Hot surfaces and Working at height

- Injury to the worker

Overall Risk Analysis Process

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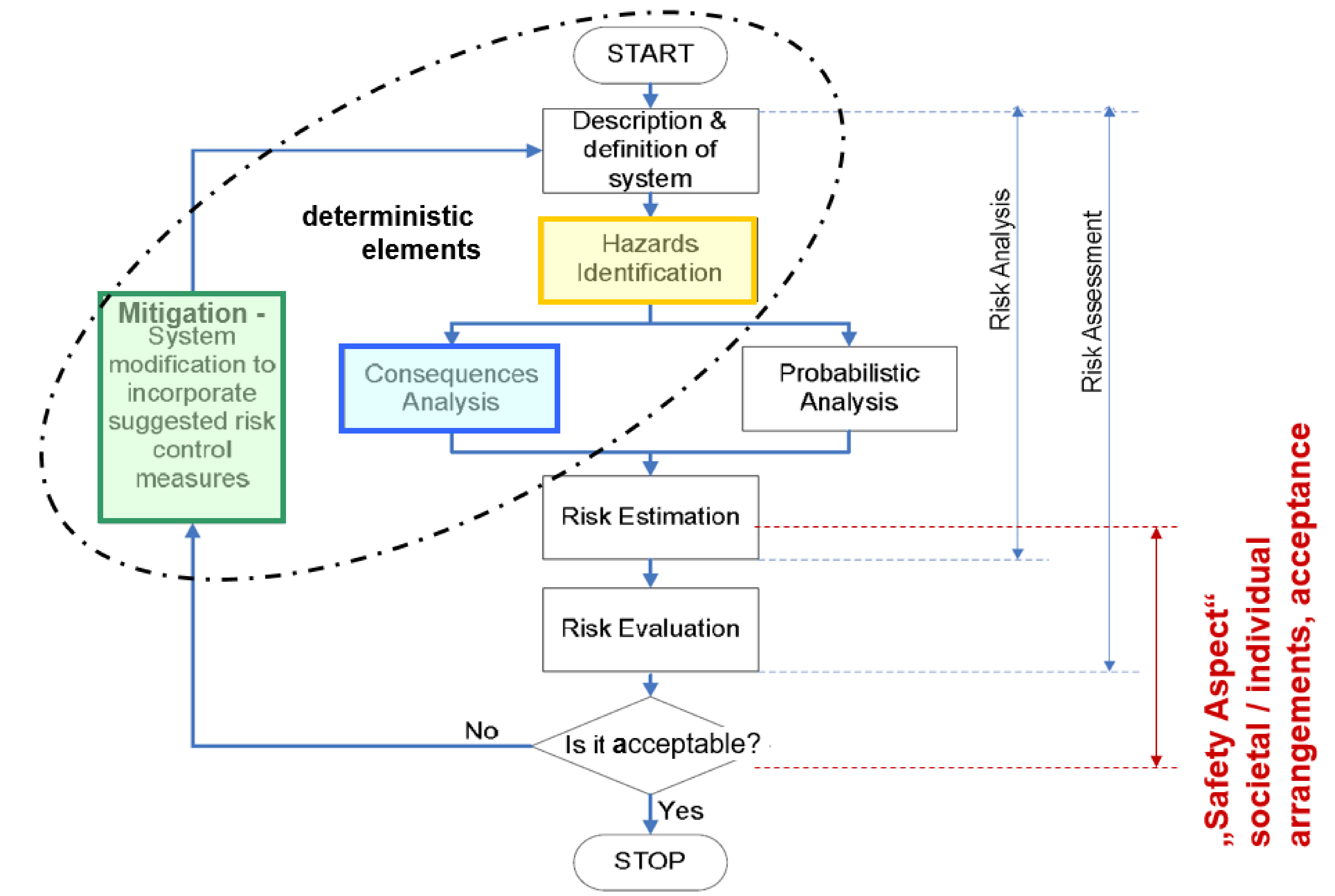
RISK product of probability of a hazard to realize and its associated consequence/damage.

RISK ANALYSIS is systematic use of information to identify sources and to estimate risk.



Risk Assessment – Methods - Overview

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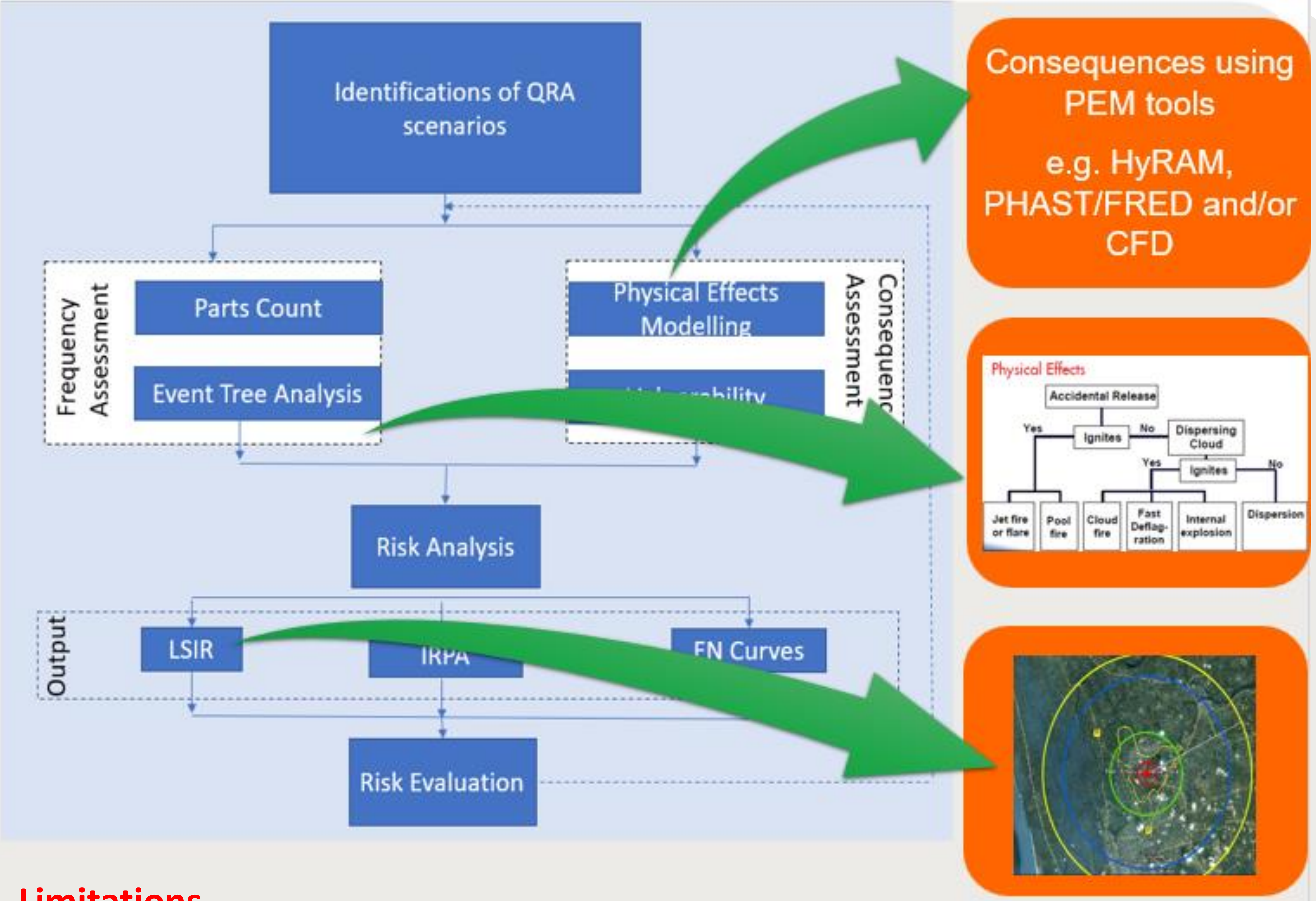
Various Methods

Qualitative Methods

- Checklist Analysis
- "What If" Analysis, Structured "What If" Technique (SWIFT)
- Hazard Identification (HAZID)
- Hazard and Operability Analysis (HAZOP)
- Risk Matrix Binning
- Failure Modes and Effects Analysis (FMEA)
- Fault Tree Analysis (FTA) - (Semi-Quantitative)

Quantitative Methods

- Event Tree Analysis and Barrier Analysis
- Probabilistic Risk Assessment (PRA)
- Quantitative Risk Assessment (QRA)
- Hydrogen safety engineering analysis
- ....



Limitations

- Unavailability of specific probabilistic parameters e.g failure rate data

Risk Acceptance Criteria

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Risk acceptance criterion defines the overall risk level that is considered acceptable,

- The criteria used for the evaluation of the need for risk reducing measures,
- to be defined prior to initiating the risk analysis.

Qualitative assessment

- Qualitative risk matrix
- Equivalent criteria

Quantitative assessment

- Individual/societal risk – focusing on a person/population
  - LSIR/IR/FN 1e-05/year (industrial area) /1e-06/year (Residential areas)

LH2 Transportation and Storage QRM			Consequence Severity				
			1	2	3	4	5
			Slight Effect No Damage	Minor Injury Minor Damage	Major Injury Moderate Damage	Up to 3 Fatalities Major Damage	More than 3 Fatalities Massive Damage
Likelihood	5	Probable	10	9	1	0	0
	4	Very Possible	92	17	6	1	0
	3	Possible	157	42	31	29	1
	2	Unlikely	154	72	42	35	23
	1	Extremely Unlikely	34	21	74	121	121

Example for a Qualitative Risk Matrix (QRM) binning of 60 events with 1093 cases for LH2 transport and storage at a refuelling station

High: Risk is not acceptable. Remedial actions are needed

Medium: Risk is not acceptable. Remedial actions are needed.

Low: Acceptable. No mitigations measures are required

Mitigation Systems or Risk Control Measures

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Safe design

- Material resisting chemical, thermal and mechanical exposure
- Pressure bearing components meeting the Pressure Equipment Directive (PED) requirements
- Piping, fitting and joints meeting PED requirements
- Leak proof connections – welded connection and minimizing the joints/fittings
- Ventilation system in the enclosure

Detection systems

- Hydrogen gas/fire detection system (UV-IR), and heat detectors
- Temperature and pressure sensors

Ignition control

- Grounding and electrical equipment approved for classified area

Others

- Pressure relief devices, Safe venting of hydrogen and oxygen and partial autocatalytic recombiners
- Detonation flame arrestors or nitrogen purging, inerting of the mixture, explosion hatch or vent panels

Conclusion

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- Hydrogen production by electrolysis is a promising option.
- For large scale production, risk associated Hydrogen and oxygen needs to be understood/managed.
- Risk evaluation/estimation is needed to check whether present risk is acceptable level.
- Risk can be further reduced by using risk reduction measures.

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