Safety in Testbeds for Fuel Cell Systems and H_2ICE

H2View Webinar

Speakers:

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Maria Santos

Harald Pongratz

Content

Intro

AVL H_2 & Fuel Cell Testing Technologies

H_2

The common denominator across various applications

Test beds

Applications Hydrogen ICE & Fuel Cell systems

Risks

Risk mitigation strategies and safety assessment measures

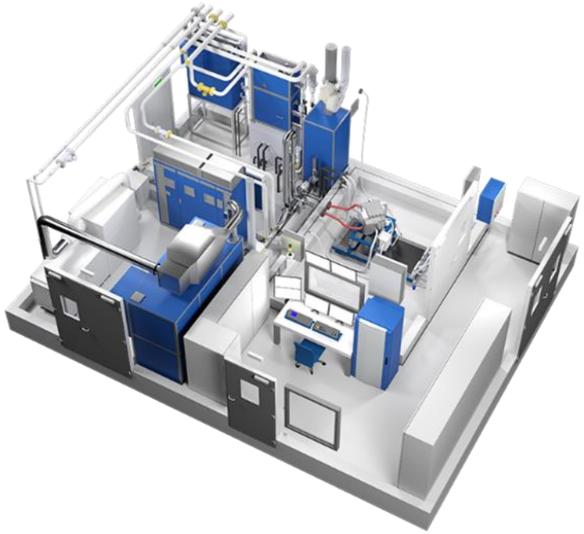
Conclusion

We Owe It to the Planet

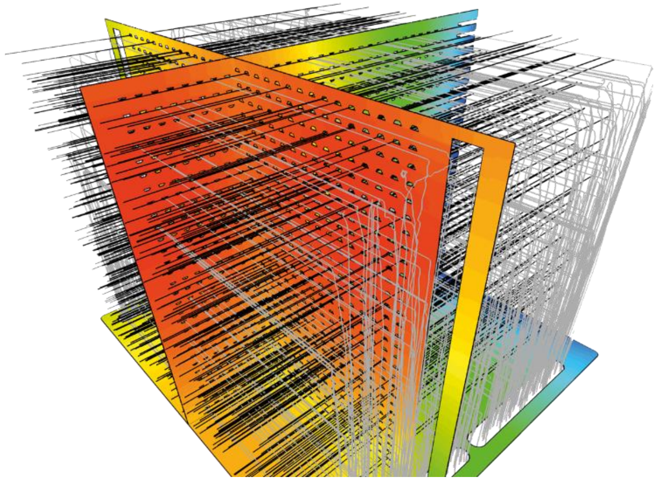
It is our duty as an organization to contribute to the resolution of social, cultural and global issues – especially with regards to environmental protection, sustainability and global emission reduction.

360° Hydrogen competence

ENGINEERING SERVICES (PTE)



INSTRUMENTATION AND TEST SYSTEMS (ITS)



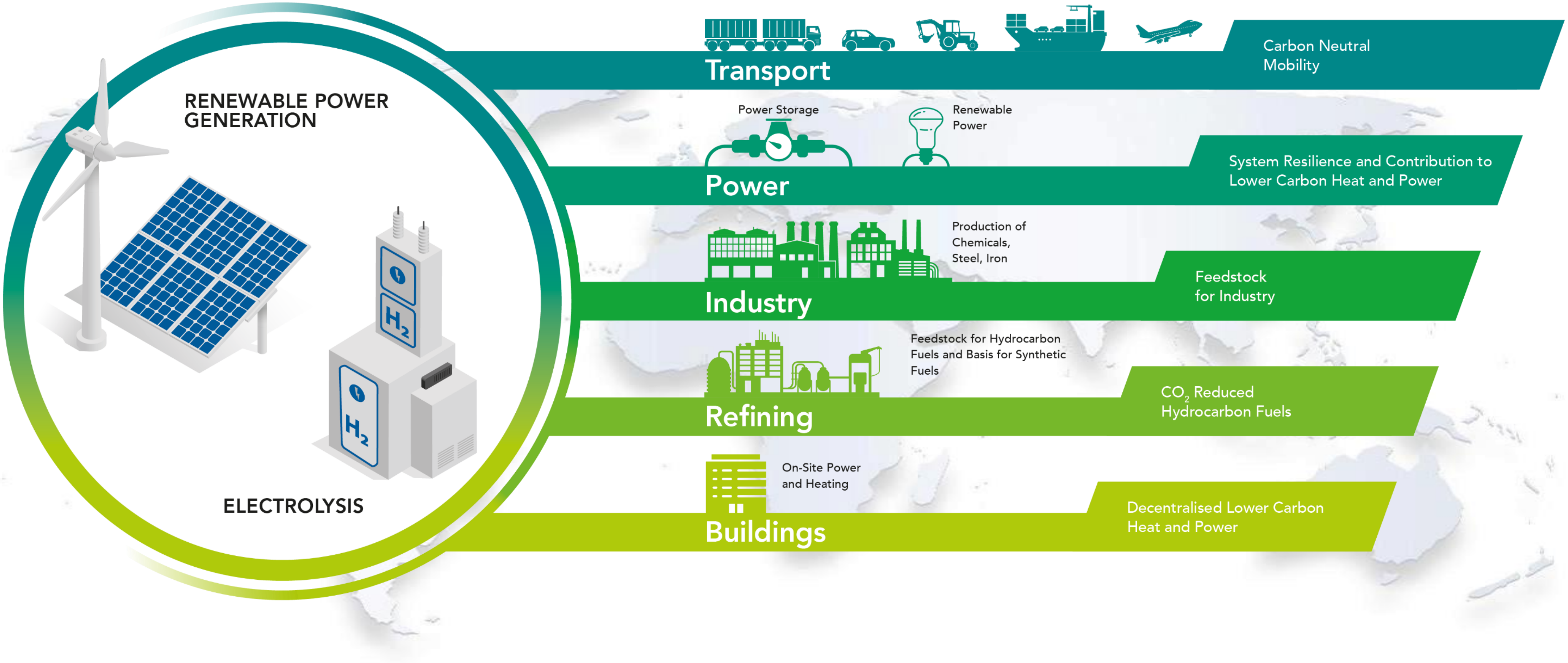
ADVANCED SIMULATION TECHNOLOGIES (AST)

Locations **6**

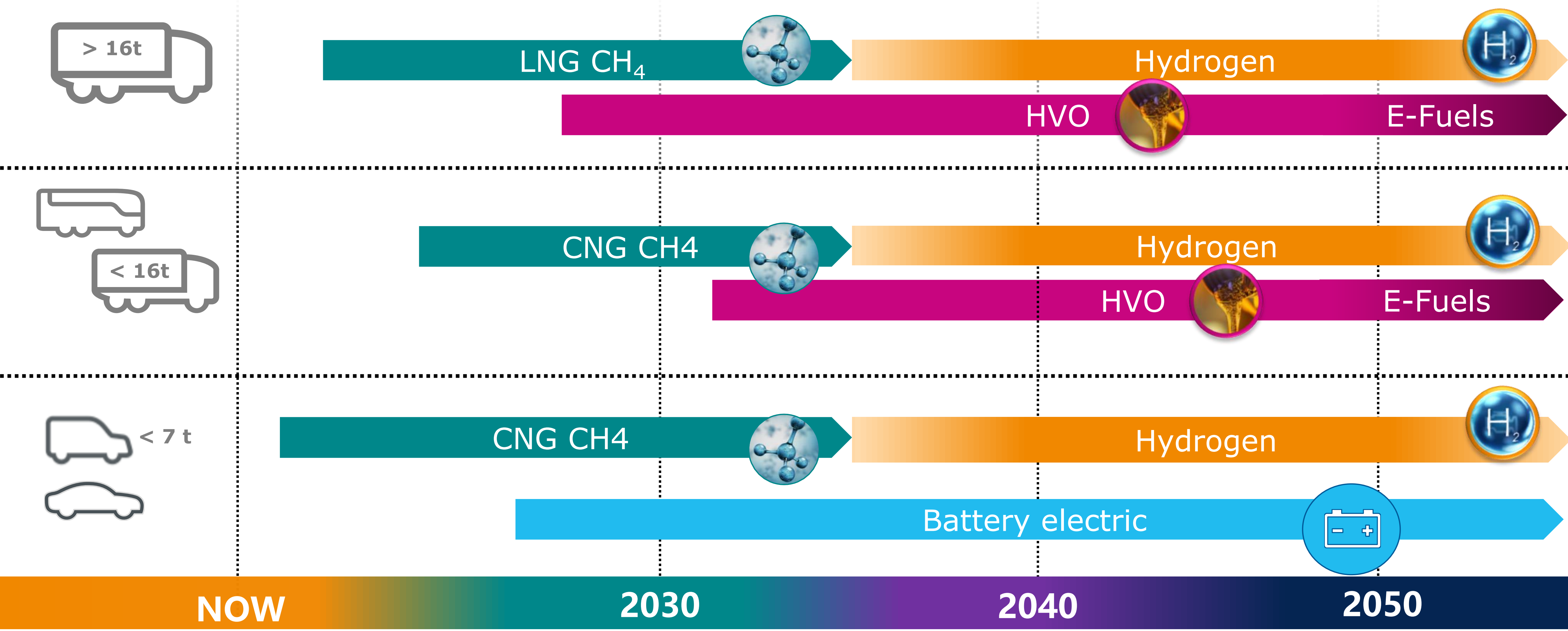
Experts **600**

Patents **>200**

Hydrogen - the Common Denominator across Industries



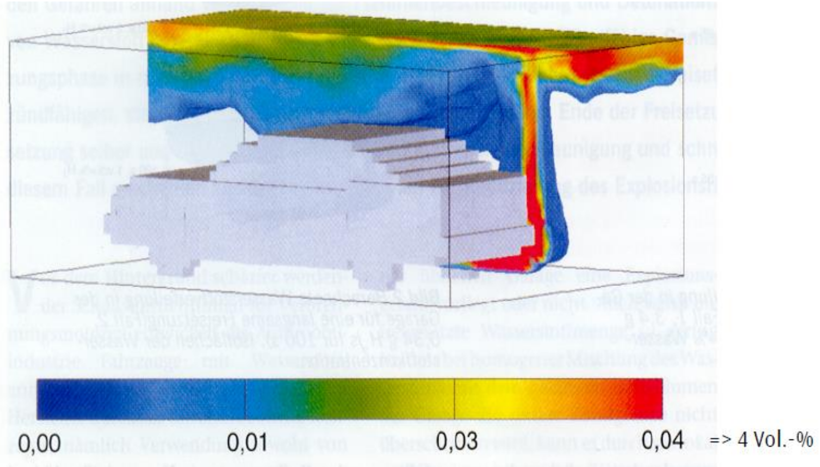
Alternative Fuel Scenario



H_2 – Physical properties

Substance	Substance Name	Relative density gas [AIR = 1]	LEL Vol(%)	UEL Vol(%)	Ignition temp. (°C)	Temp. class	Min. Ignition Energy [mJ]	Gas class	Calorific energy [kWh/kg]
H_2	Hydrogen	**0,0695 (1/14)**	**4**	77	560	T1	**0,016**	IIC	33
C_3H_8	Propane	1,55	1,7	10,8	470	T1	0,24	IIA	13
NH_3	Ammonia	0,55	14	32,5	630	T1	14	IIA	5,2

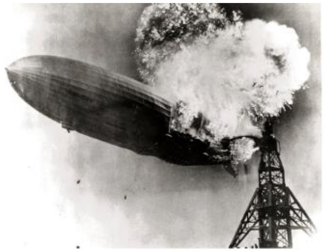
Values: GESTIS; TRGS 727

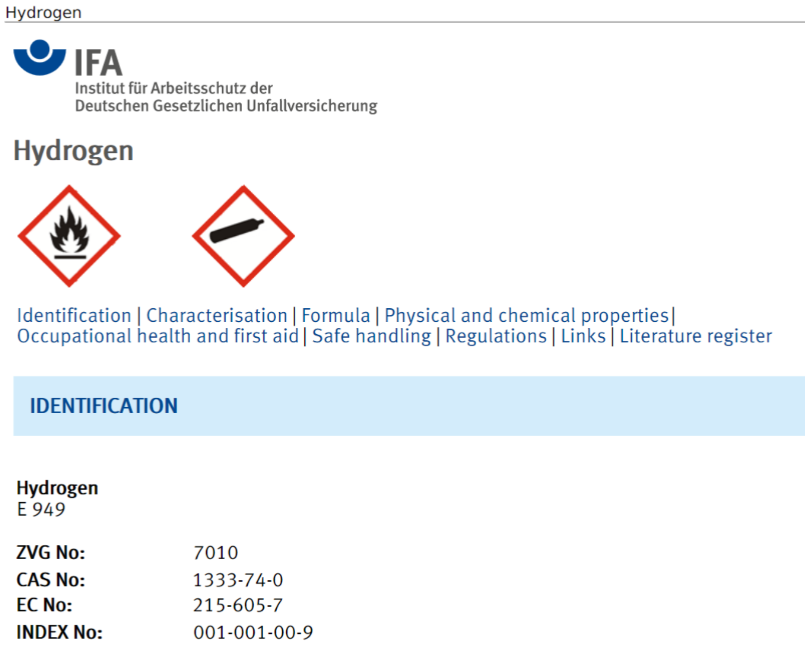


Danger potential hydrogen

Potential sources of danger when handling hydrogen:

- Pressure
- Fire
- Explosion
- Embrittlement
- Temperature





Hydrogen

IFA
Institut für Arbeitsschutz der
Deutschen Gesetzlichen Unfallversicherung

Hydrogen

Identification | Characterisation | Formula | Physical and chemical properties | Occupational health and first aid | Safe handling | Regulations | Links | Literature register

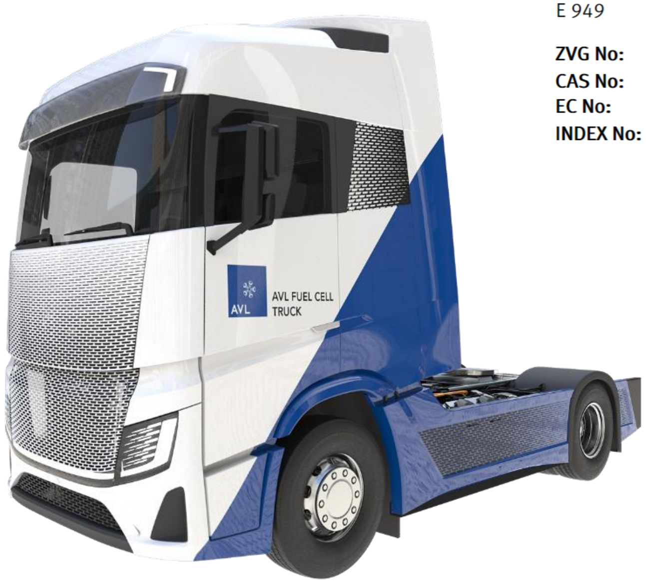
IDENTIFICATION

Hydrogen
E 949

ZVG No:	7010
CAS No:	1333-74-0
EC No:	215-605-7
INDEX No:	001-001-00-9

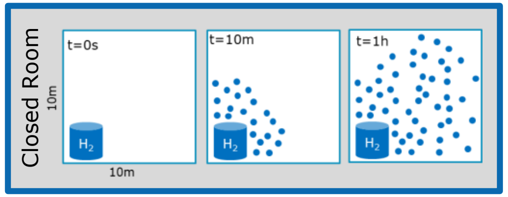
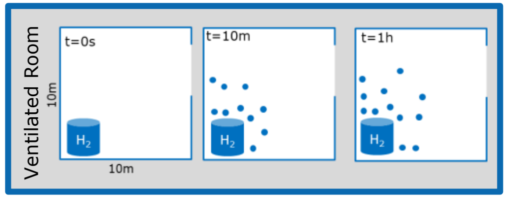
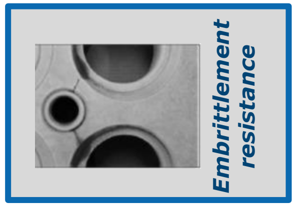
GESTIS-Stoffdatenbank (dguv.de)

KEYTECH4EV – AVL FC Car

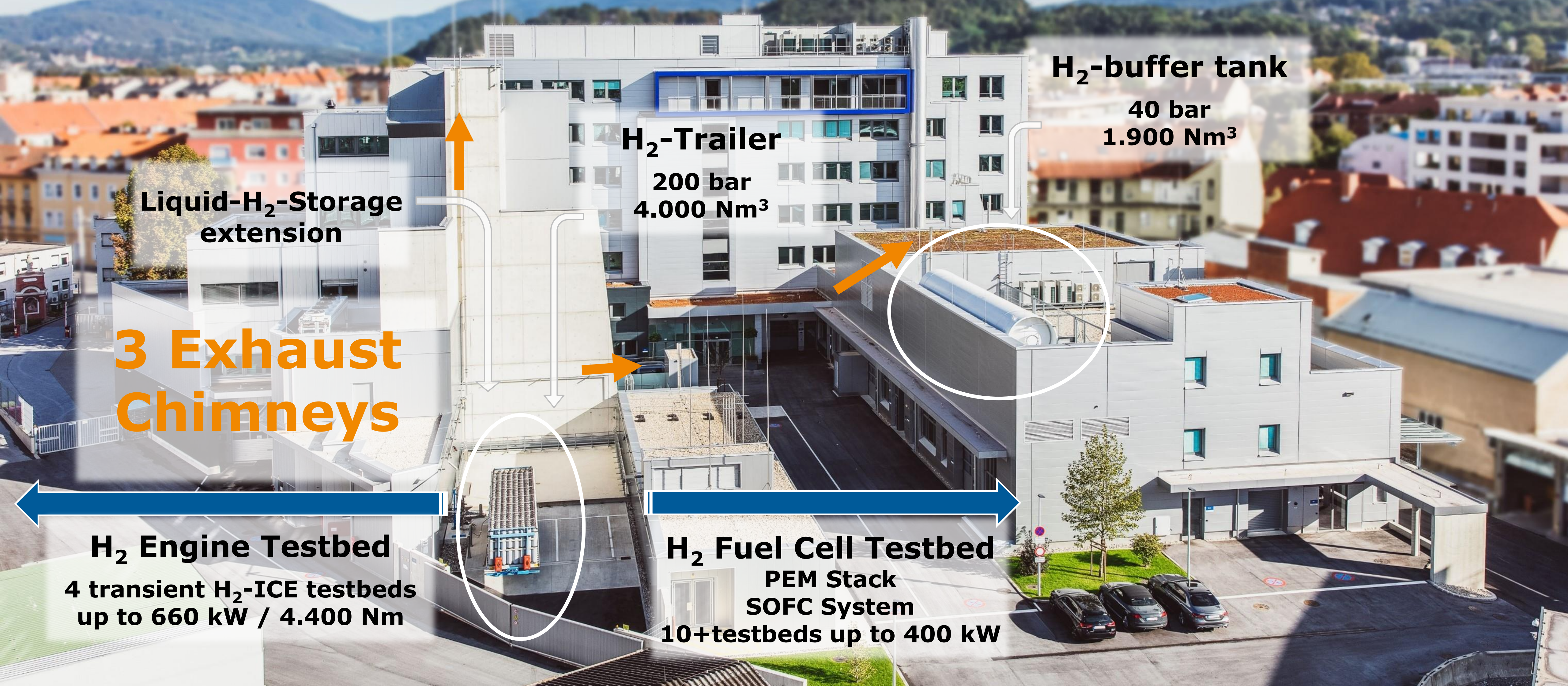


AVL FC Truck

Hydrogen Properties and Impact on the Test Cell

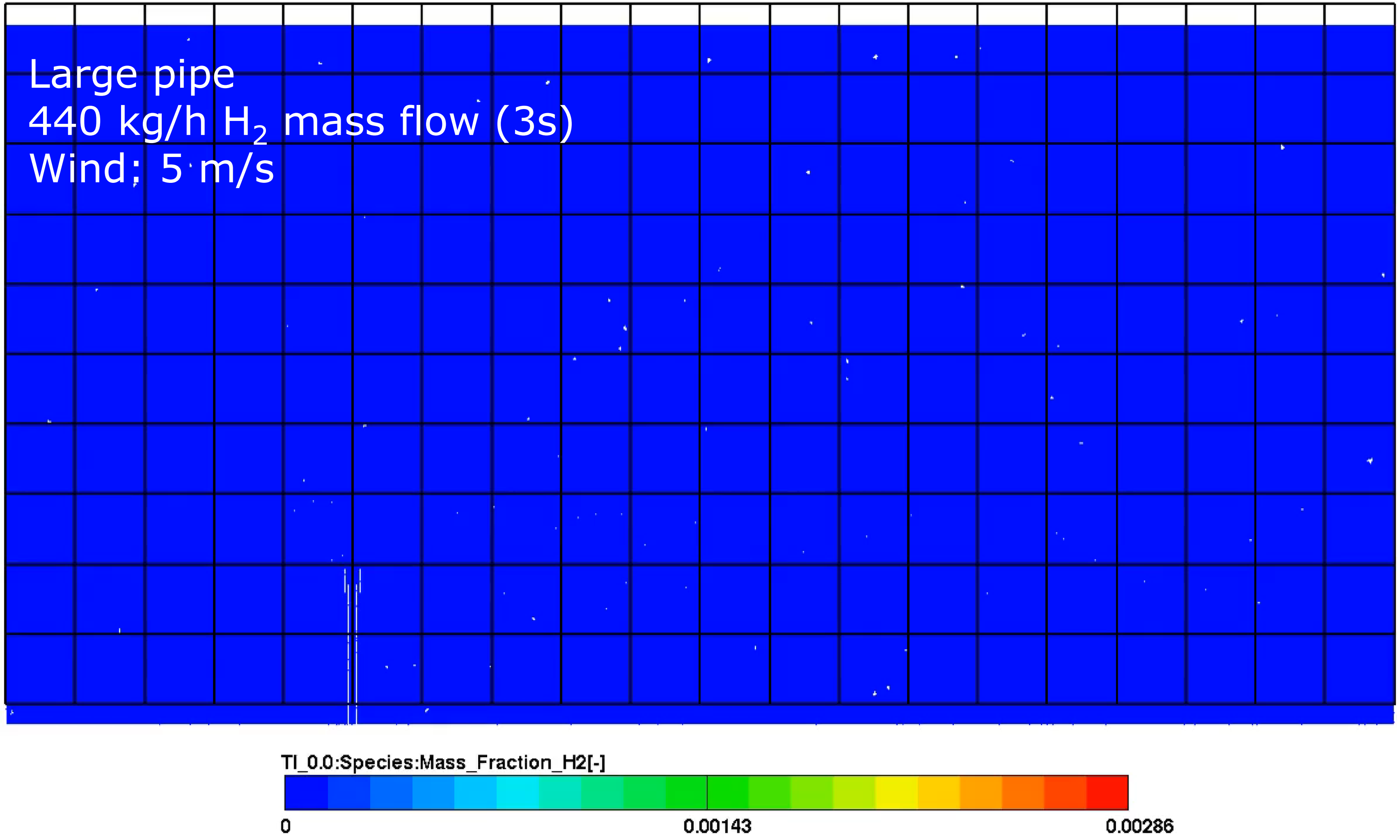
	Facts	Impacts in test cell
Diffusion	• High diffusion • Risk of H_2 concentration in enclosures	 
Buoyancy	• Mixture of hydrogen lighter than the air • Hydrogen rises up	
Explosion	• Highly Combustible • Hydrogen alone cannot explode • Needs oxidizer (air) and ignition source • Keep H_2 concentration under LEL (< 4%)	 
Others	• Embrittlement • H_2 is not smelly • Can be displaced by other gases as N_2 • Need Certification	  

AVL H_2 & Fuel Cell test center



Simulation of Hydrogen Cloud

Break of a valve



Black colour indicates H_2 ignition limit and above

H2 Applications

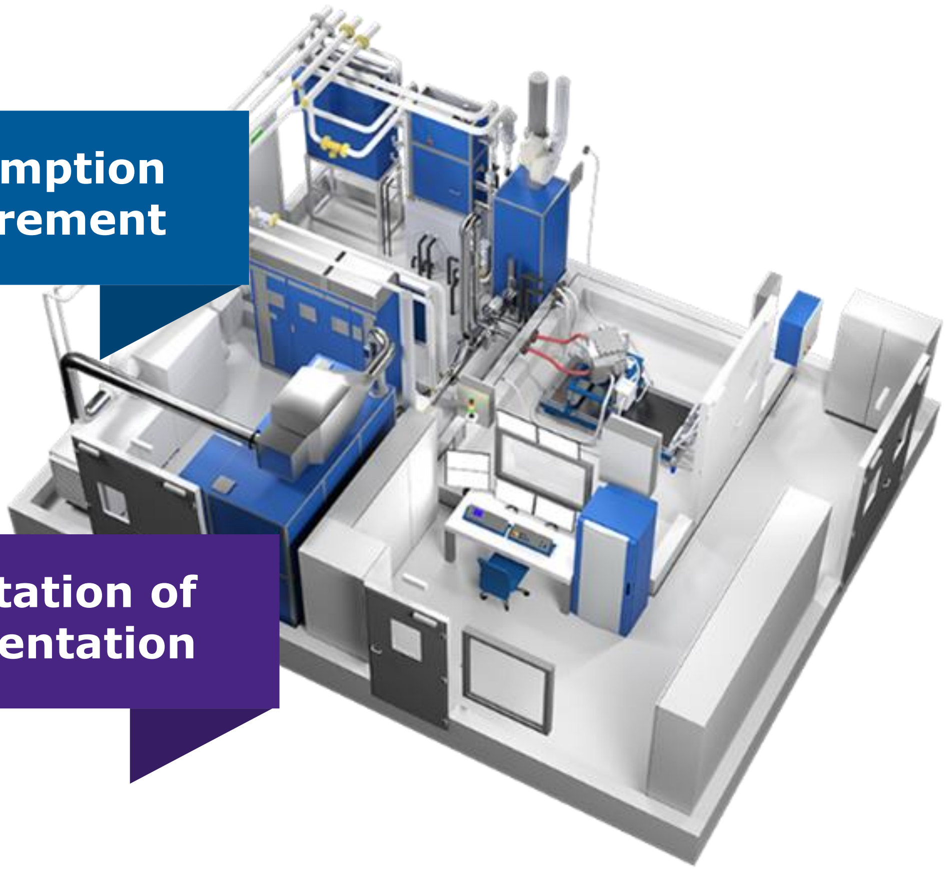
H_2 Supply

H_2 Consumption Measurement

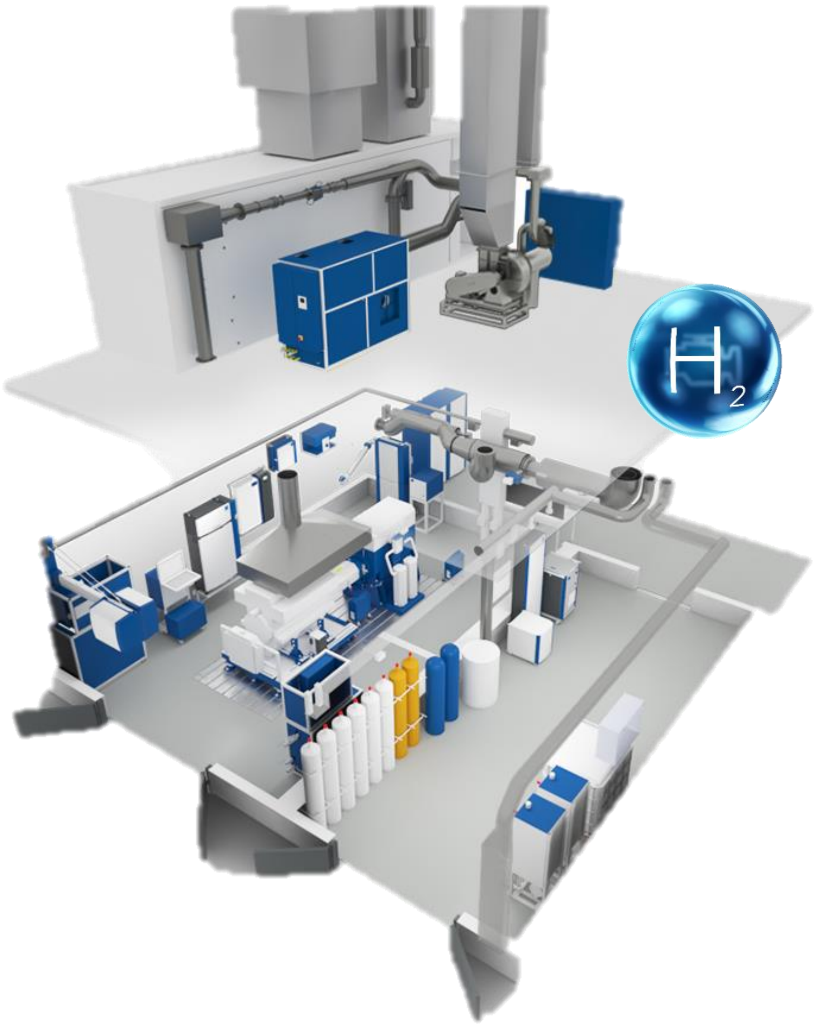
Air Handling, Exhaust & ATEX Ventilation

Adaptation of Instrumentation

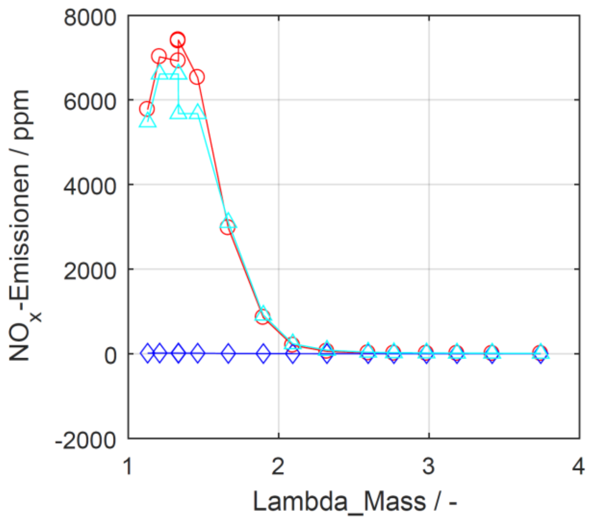
Test Cell & Facility Safety

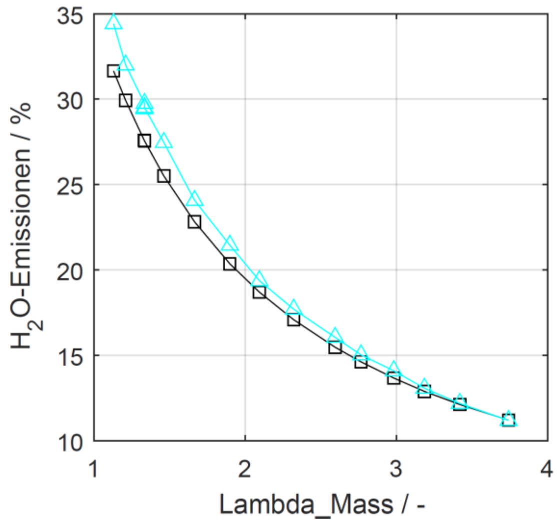


Application H2 ICE

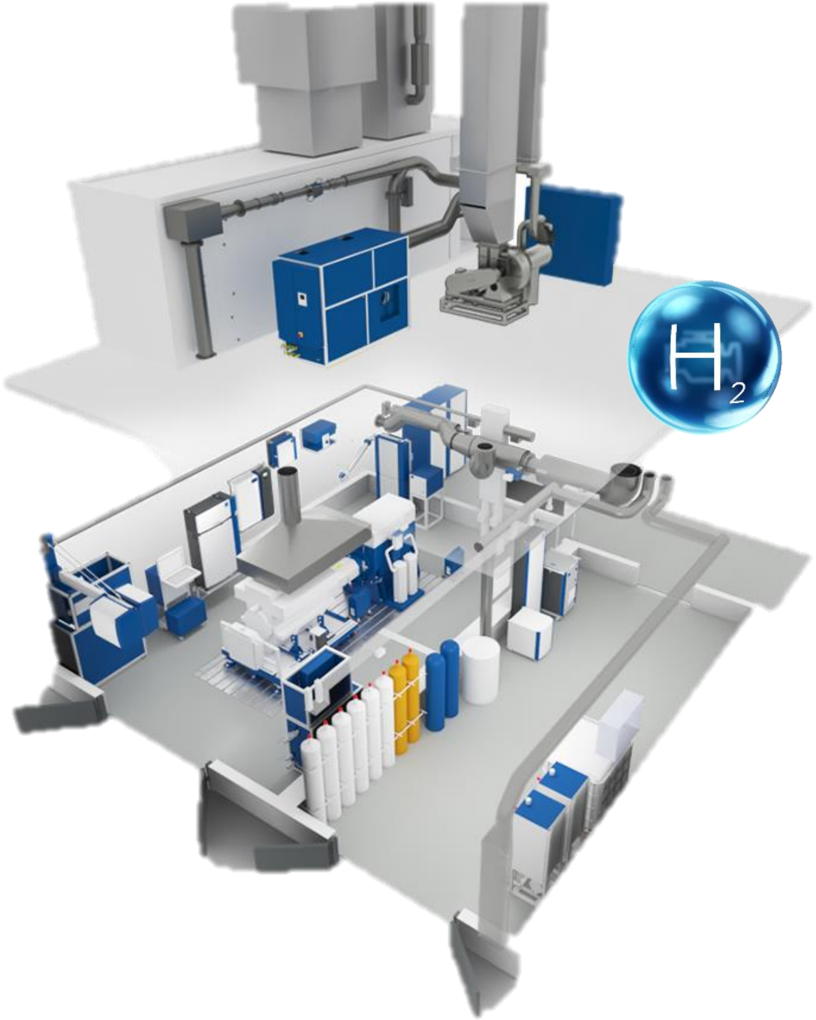


Testbed Safety Challenges	
Diffusion	• High diffusion • Risk of H_2 concentration in enclosures
Explosion	• Needs air and ignition source • Keep H_2 concentration under LEL (< 4%)
 **H_2 ICE**	• NO_x emissions control at low λ • High H_2O Concentration in Exhaust • H_2 Slip in Blowby and Exhaust





Application H2 ICE



Testbed Safety Challenges

Diffusion	• High diffusion • Risk of H_2 concentration in enclosures	
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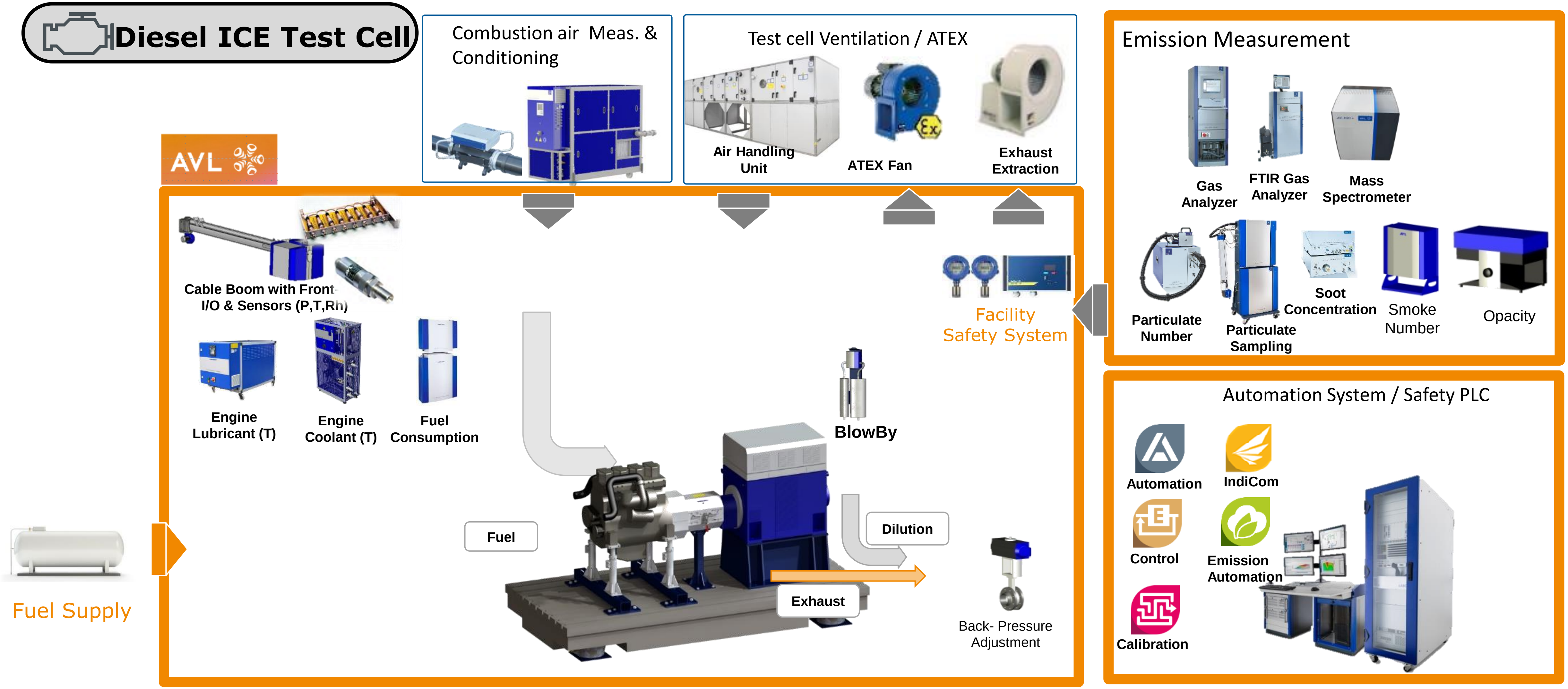
H_2 ICE	• NO_x emissions control • High H_2O Concentration in Exhaust • H_2 Slip in Blowby and Exhaust	

H_2 Pressure

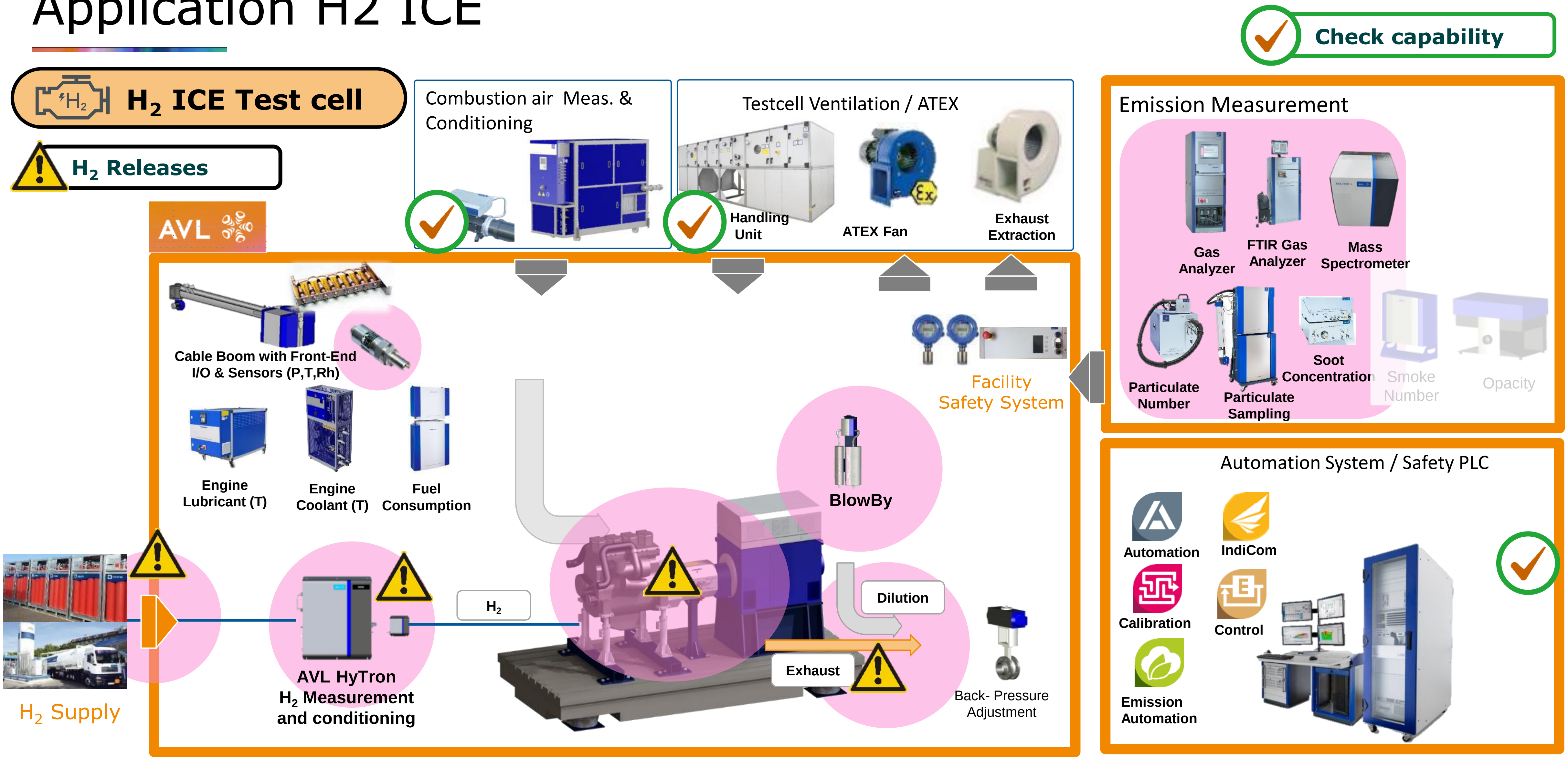
Multipoint Injection	LPDirect Injection	HPDirect Injection
10-20 bar	**40-100 bar**	**>200 bar**



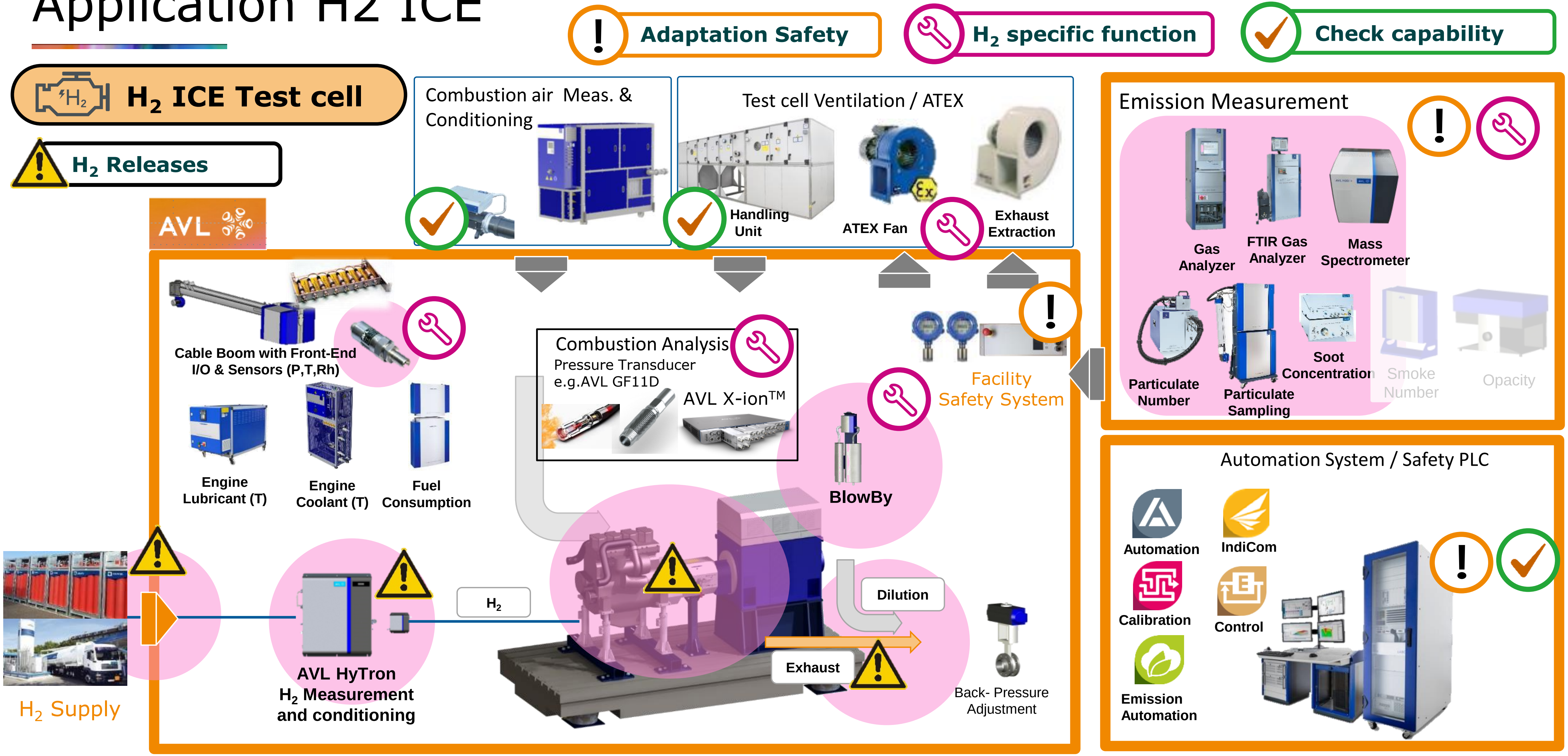
Application H2 ICE



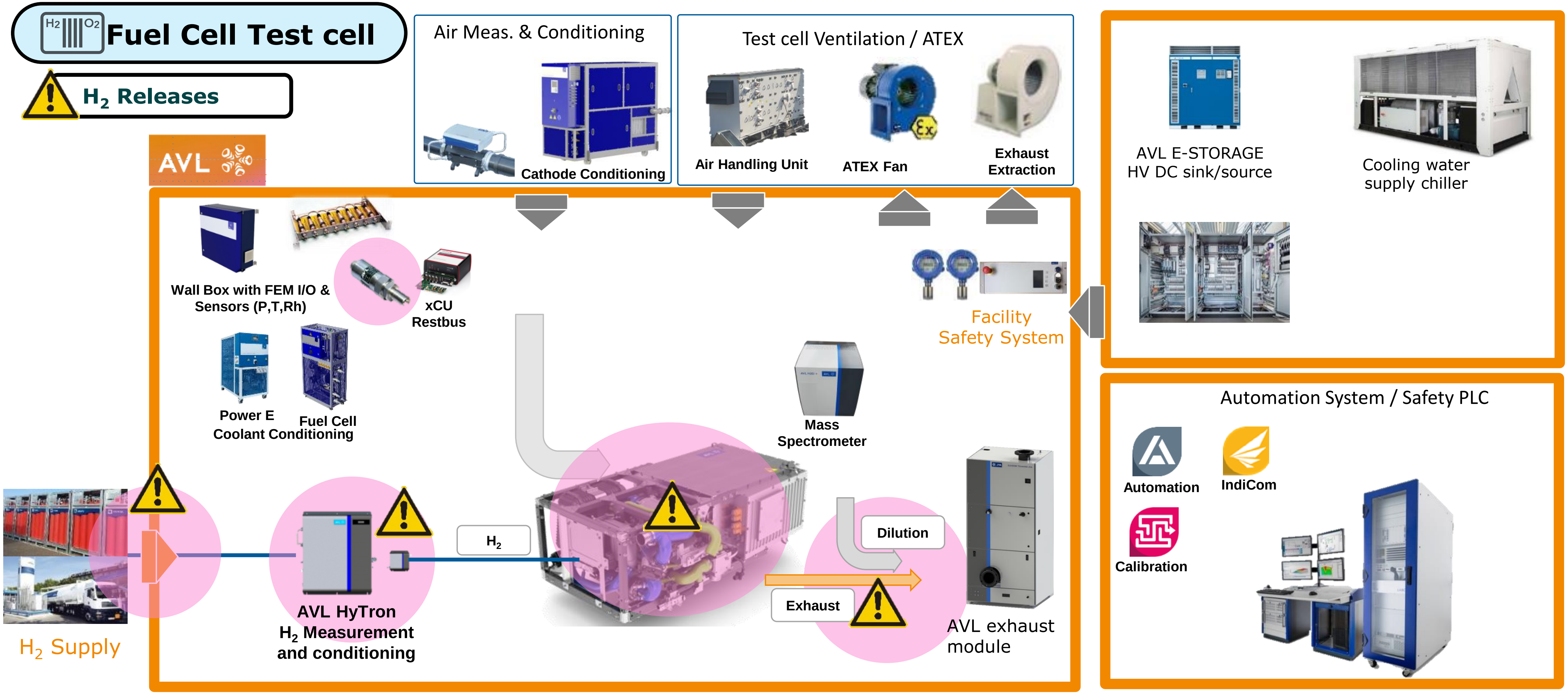
Application H2 ICE



Application H2 ICE



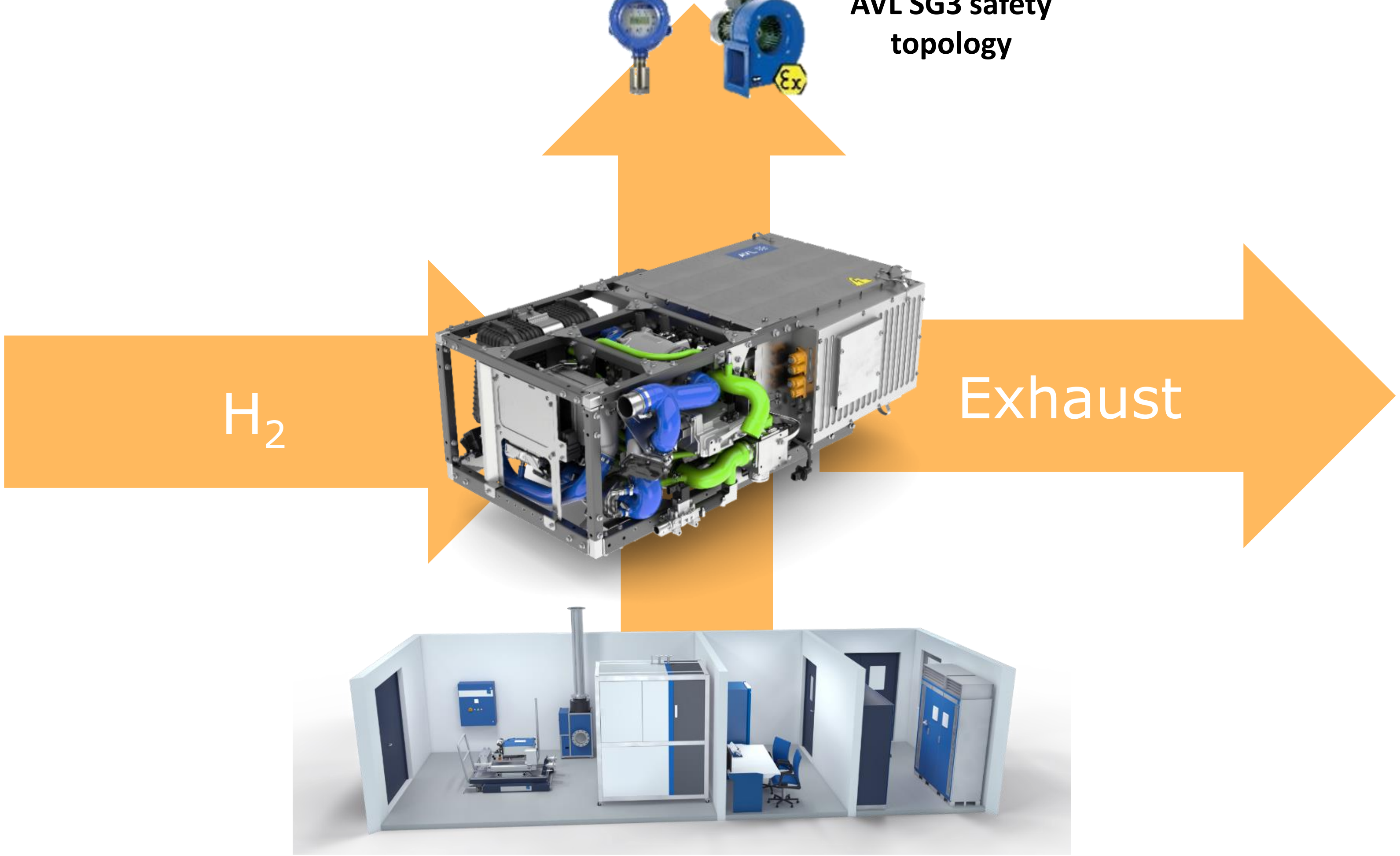
Application Fuel Cell - Hazardous Zones



Safety relevant Modules

TÜV certified safety system
AVL SG3 safety topology

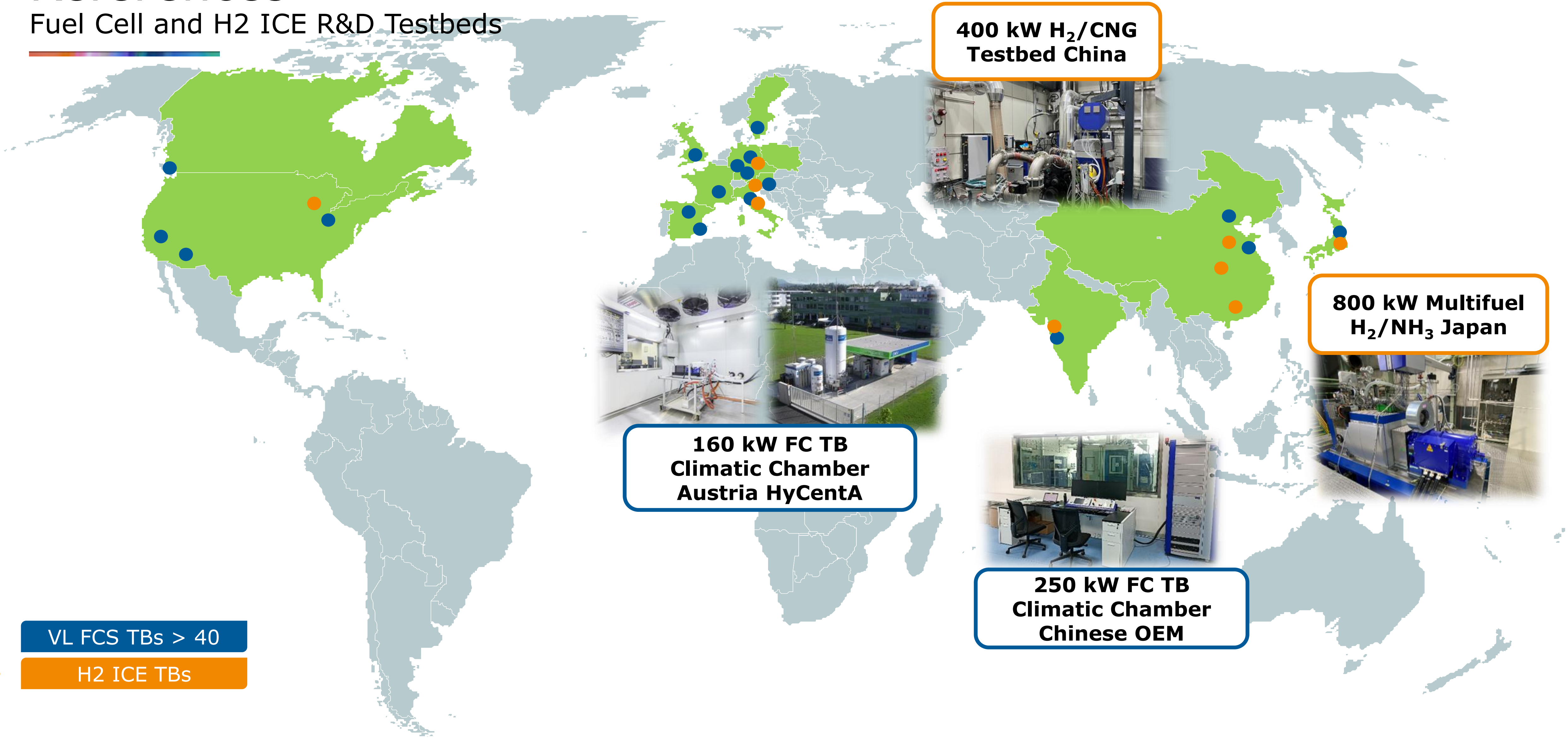
Hydrogen supply and flow measurement
AVL HyTron™



Removal of condensate to avoid hydrogen in the drainage system
AVL Exhaust Module

References

Fuel Cell and H2 ICE R&D Testbeds



400 kW H_2/CNG Testbed China

160 kW FC TB Climatic Chamber Austria HyCentA

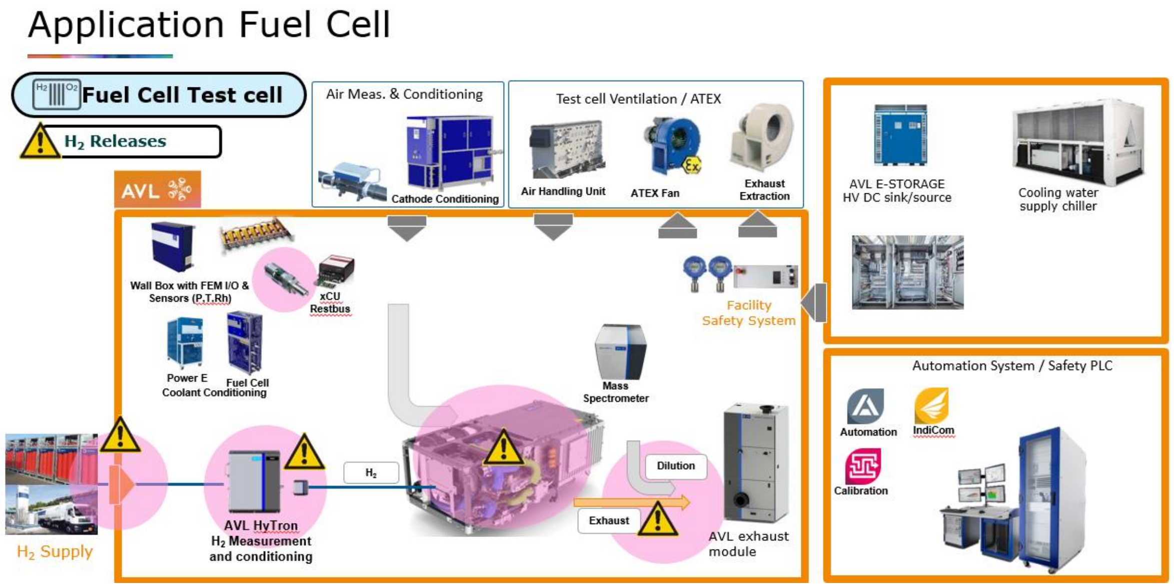
250 kW FC TB Climatic Chamber Chinese OEM

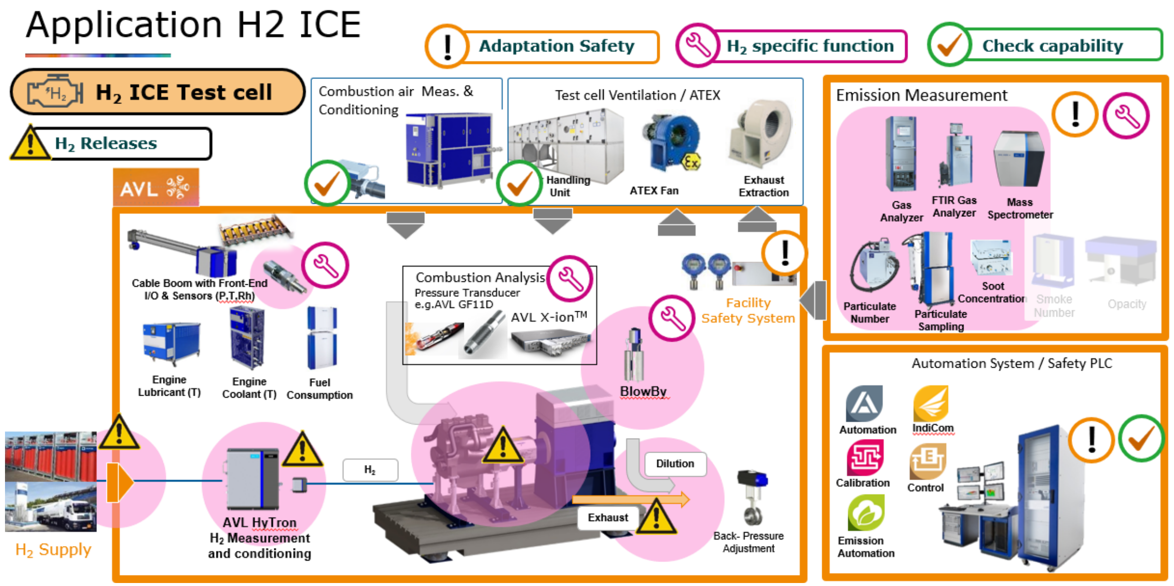
800 kW Multifuel H_2/NH_3 Japan

VL FCS TBs > 40

H2 ICE TBs

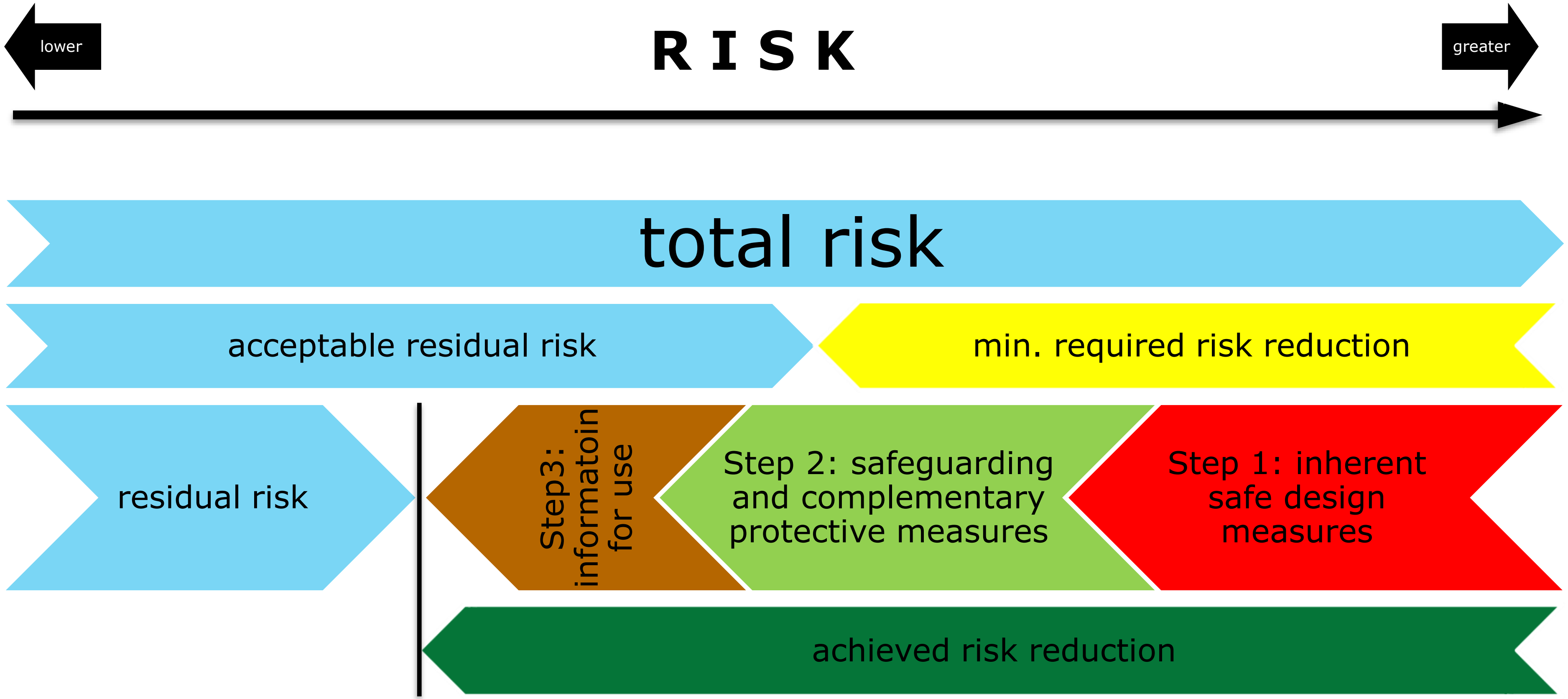
Risk reduction process





How do we minimize the risk?

Risk reduction process acc. ISO 12100



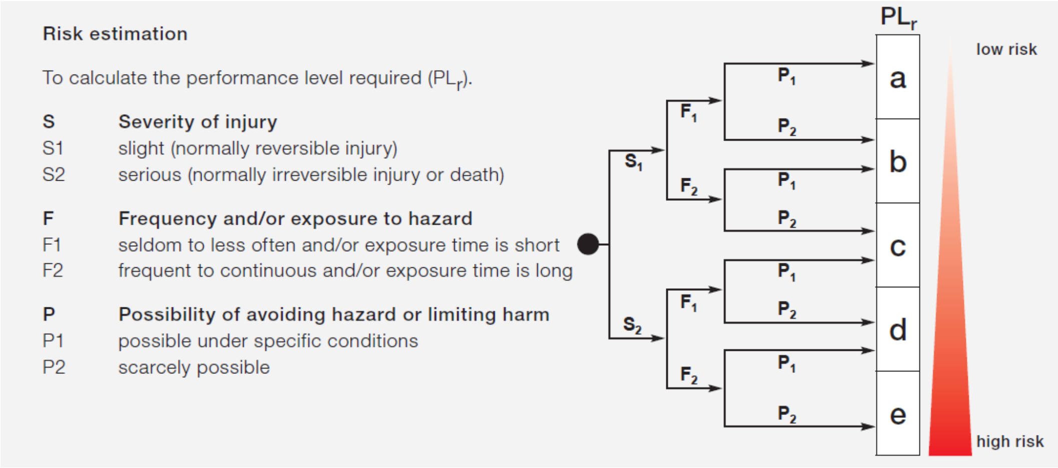
Safety Engineering @AVL

Basic Engineering:

- Risk assessment
- Safety concept
- Selection of safety related components
- Interface engineering subsystems
- Interface engineering facilities

Detailed Engineering

- Calculation of functional safety
- Detailed schematics
- Safety matrix
- Validation of safety system
- System documentation



EXPLOSION PROTECTION

Explosion is a sudden oxidation or decomposition reaction with rise in temperature, pressure, or both at the same time.

Explosion protection is a branch of technology that deals with protection against the development of explosions and their effects.

Differentiation of an explosion in **Deflagration** and **Detonation**.

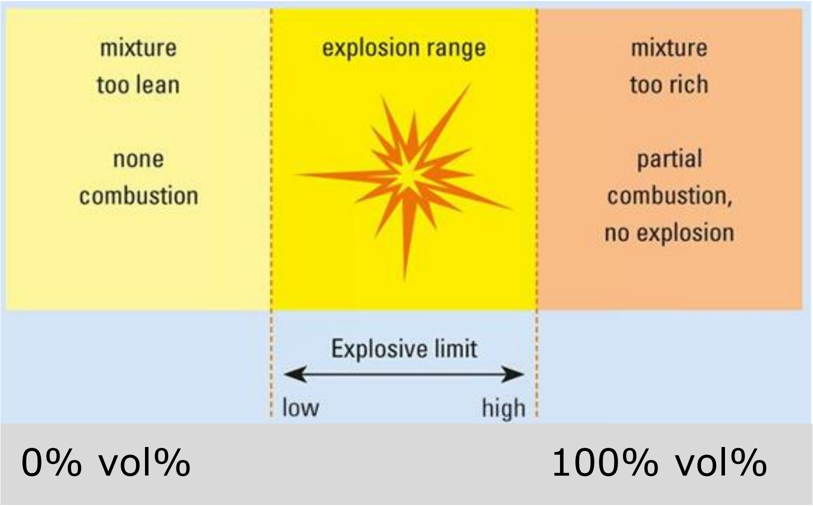
A **deflagration** has an explosion pressure of about 10 bar (Gas) to 14 bar (Dust), the propagation speed is about 1.000 m/s.

A **Detonation** has an explosion pressure of about 20 bar, the propagation speed is about 3.000 m/s.

Effect and impact of an explosion:

Damage to people:	Pressure, flames, flying debris
Environmental impact:	Emission of toxic substances
Damage to property:	Destruction of equipment and products
Financial damage:	Loss of production, compensation costs, forfeits
Damage to image:	Reporting in public

H_2 – Physical properties – Explosive limits



Substance	Substance Name	Relative density gas [AIR = 1]	LEL Vol(%)	UEL Vol(%)	Ignition temp. (°C)	Temp. class	Min. Ignition Energy [mJ]	Gas class	Calorific energy [kWh/kg]
H_2	Hydrogen	**0,0695 (1/14)**	**4**	77	560	T1	**0,016**	IIC	33

Overview **explosion protection** Regulations

EU Directives

2014/34/EU ATEX 114	1999/92/EU ATEX 153
Manufacturer	Operator
Equipment and protective systems intended for use in potentially explosive atmospheres.	Minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres.

National laws, regulations and provisions

LAW

International Standards / Rules

- Are advantageous as aids in addition to the nationally applicable technical regulations.
- Not legally binding but their presumption of conformity creates a legal certainty for manufacturers and operators.

EN 60079-10-1	Classification of areas. Explosive gas atmospheres
EN 60079-14	Electrical installations design, selection and erection
EN 60079-17	Electrical installations inspection and maintenance
EN 1127-1	Explosion prevention and protection
TRGS, TRBS, NFPA xxx	Technical Rules

State of the art

Explosion protection measures

Tertiary Explosion Protection

Mitigate damage due to explosions

In case of accidental explosion
- Explosion-resistant design
- Explosion relief
- Explosion suppression
- etc

If not sufficient

Secondary Explosion Protection

AVOID IGNITION SOURCES

- Hot surfaces
- Flames and hot gases (including hot particles)
- Mechanically generated impact, friction and abrasion
- Electrical equipment and components
- etc.

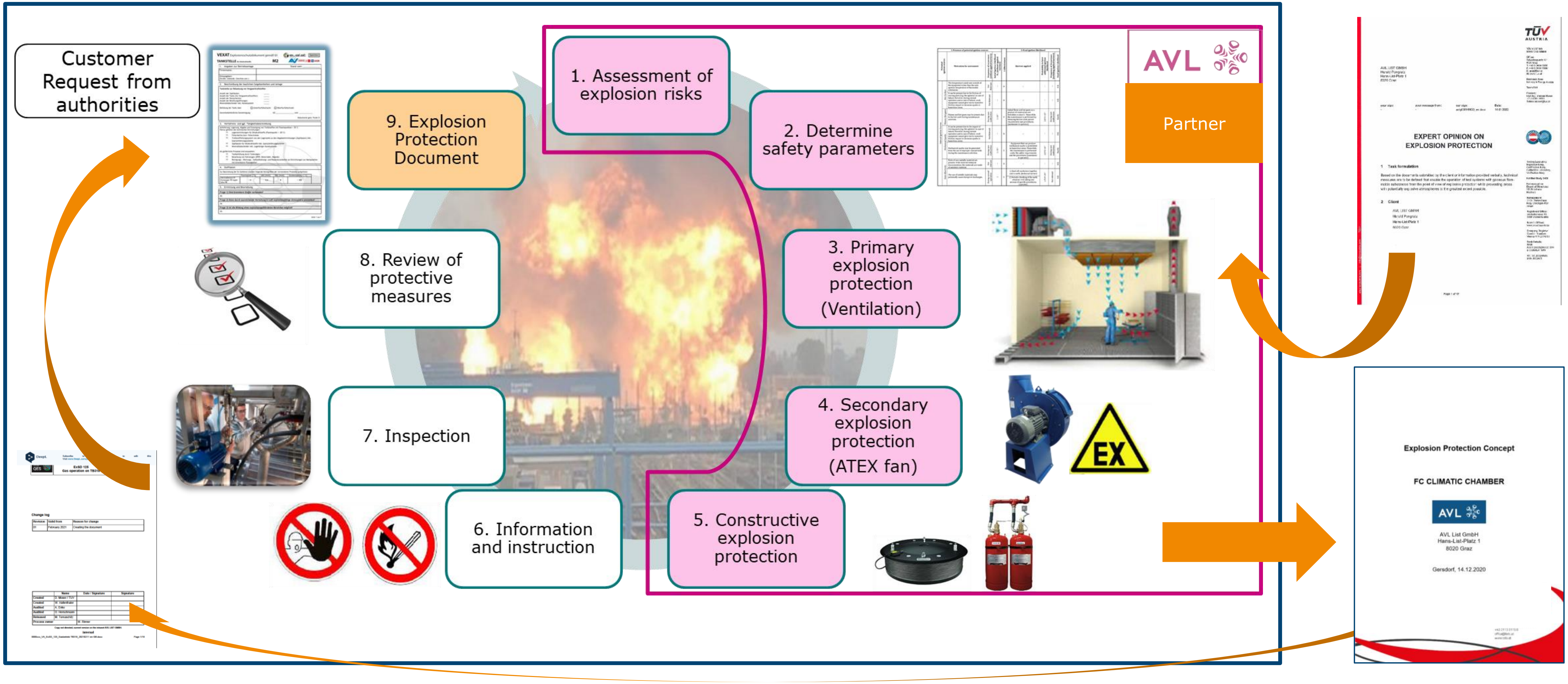
If not sufficient

Primary Explosion Protection

Avoid EXPLOSIVE ATMOSHPHER

- Tightness
- Ventilation
- Inertisation
- Evacuation
- Gas detection system

H2 ICE / FUEL CELL
Explosion protection concept



Primary Explosion Protection (ventilation requirements)

Leakage size selection / leak rate determination / Ventilation requirements
(acc. to IEC 60079)

AVL Leak Calculation v1.0

AVL

AVL Leak Calculation

IEC 60079-10-1:2020

Introduction | Data Input

General data

Customer: CUMMINS
AVL Technician: SHARMAMK
Test Cell Name: H2ICE
Comments

Gas Leak

☐ Use Default Values

Duct Pressure rel.: 60
Leak hole section: 0.025
Discharge Coefficient (Cd): 0.99

1.0 Leakage Size Selection as per IEC 60079-10-1:2020

– 42 – IEC 60079-10-1:2020 © IEC 2020

Table B.1 – Suggested hole cross sections for secondary grade of releases

Type of item	Item	Leak Considerations		
		Typical values for the conditions at which the release opening will not expand	Typical values for the conditions at which the release opening may expand, e.g. erosion	Typical values for the conditions at which the release opening may expand up to a severe failure, e.g. blow out
		S (mm²)	S (mm²)	S (mm²)
Sealing elements on fixed parts	Flanges with compressed fibre gasket or similar	≥ 0,025 up to 0,25	> 0,25 up to 2,5	(sector between two bolts) × (gasket thickness) usually ≥ 1 mm
	Flanges with spiral wound gasket or similar	0,025	0,25	(sector between two bolts) × (gasket thickness) usually ≥ 0,5 mm
	Ring type joint connections	0,1	0,25	0,5
	Small bore connections up to 50 mm[a]	≥ 0,025 up to 0,1	> 0,1 up to 0,25	1,0
Sealing elements on moving parts at low speed	Valve stem packings	0,25	2,5	To be defined according to Equipment Manufacturer's Data but not less than 2,5 mm² [d]
	Pressure relief valves[b]	0,1 × (orifice section)	NA	NA
Sealing elements on moving parts at high speed	Pumps and compressors[c]	NA	≥ 1 up to 5	To be defined according to Equipment Manufacturer's Data and/or Process Unit Configuration but not less than 5 mm² [d and e]

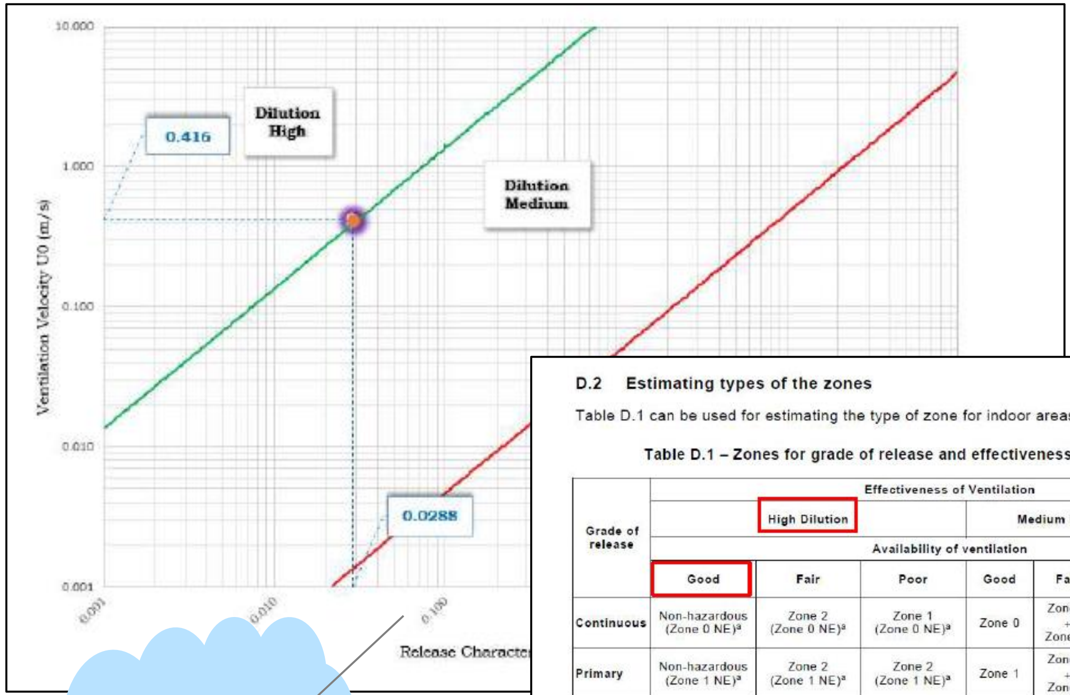
[a] Hole cross sections suggested for ring joints, threaded connections, compression joints (e.g. metallic compression fittings) and rapid joints on small bore piping.

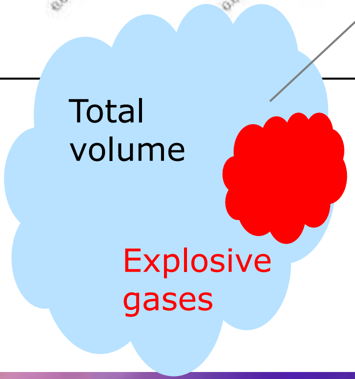
[b] This item does not refer to full opening of the valve but to various leaks due to malfunction of the valve components. Specific applications could require a hole cross section bigger than suggested.

[c] Reciprocating Compressors – The frame of compressor and the cylinders are usually not items that leak but the piston rod packings and various pipe connections in the process system.

[d] Equipment Manufacturer's Data – Cooperation with equipment's manufacturer is required to assess the effects in case of an expected failure (e.g. the availability of a drawing with details relevant to sealing devices).

[e] Process Unit Configuration – In certain circumstances (e.g. a preliminary study), an operational analysis to define the maximum accepted release rate of flammable substance may compensate lack of equipment





D.2 Estimating types of the zones

Table D.1 can be used for estimating the type of zone for indoor areas and open areas.

Table D.1 – Zones for grade of release and effectiveness of ventilation

Grade of release	Effectiveness of Ventilation						
	High Dilution			Medium Dilution			Low Dilution
	Availability of ventilation						
	Good	Fair	Poor	Good	Fair	Poor	Good, fair or poor
Continuous	Non-hazardous (Zone 0 NE)[a]	Zone 2 (Zone 0 NE)[a]	Zone 1 (Zone 0 NE)[a]	Zone 0	Zone 0 + Zone 2[c]	Zone 0 + Zone 1	Zone 0
Primary	Non-hazardous (Zone 1 NE)[a]	Zone 2 (Zone 1 NE)[a]	Zone 2 (Zone 1 NE)[a]	Zone 1	Zone 1 + Zone 2	Zone 1 + Zone 2	Zone 1 or zone 0[c]
Secondary[b]	Non-hazardous (Zone 2 NE)[a]	Non-hazardous (Zone 2 NE)[a]	Zone 2	Zone 2	Zone 2	Zone 2	Zone 1 and even Zone 0[d]

[a] Zone 0 NE, 1 NE or 2 NE indicates a theoretical zone which would be of negligible extent under normal conditions.

[b] The Zone 2 area created by a secondary grade of release may exceed that attributable to a primary or continuous grade of release; in this case, the greater distance should be taken.

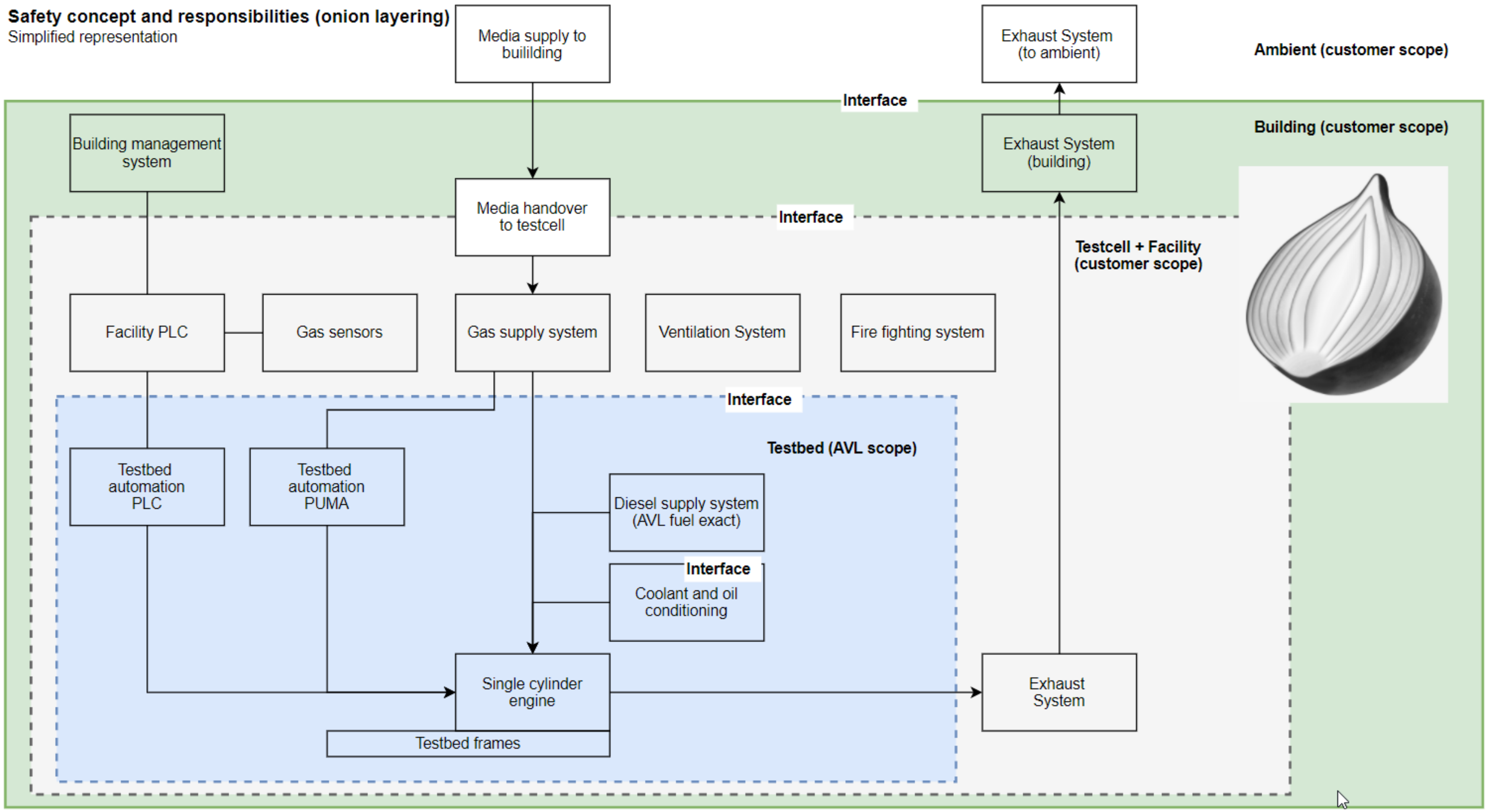
[c] Zone 1 is not needed here. I.e. small Zone 0 is in the area where the release is not controlled by the ventilation and larger Zone2 for when ventilation fails.

[d] Will be Zone 0 if the ventilation is so weak and the release is such that in practice an explosive gas atmosphere exists virtually continuously (i.e. approaching a 'no ventilation' condition).

'+' signifies 'surrounded by'.

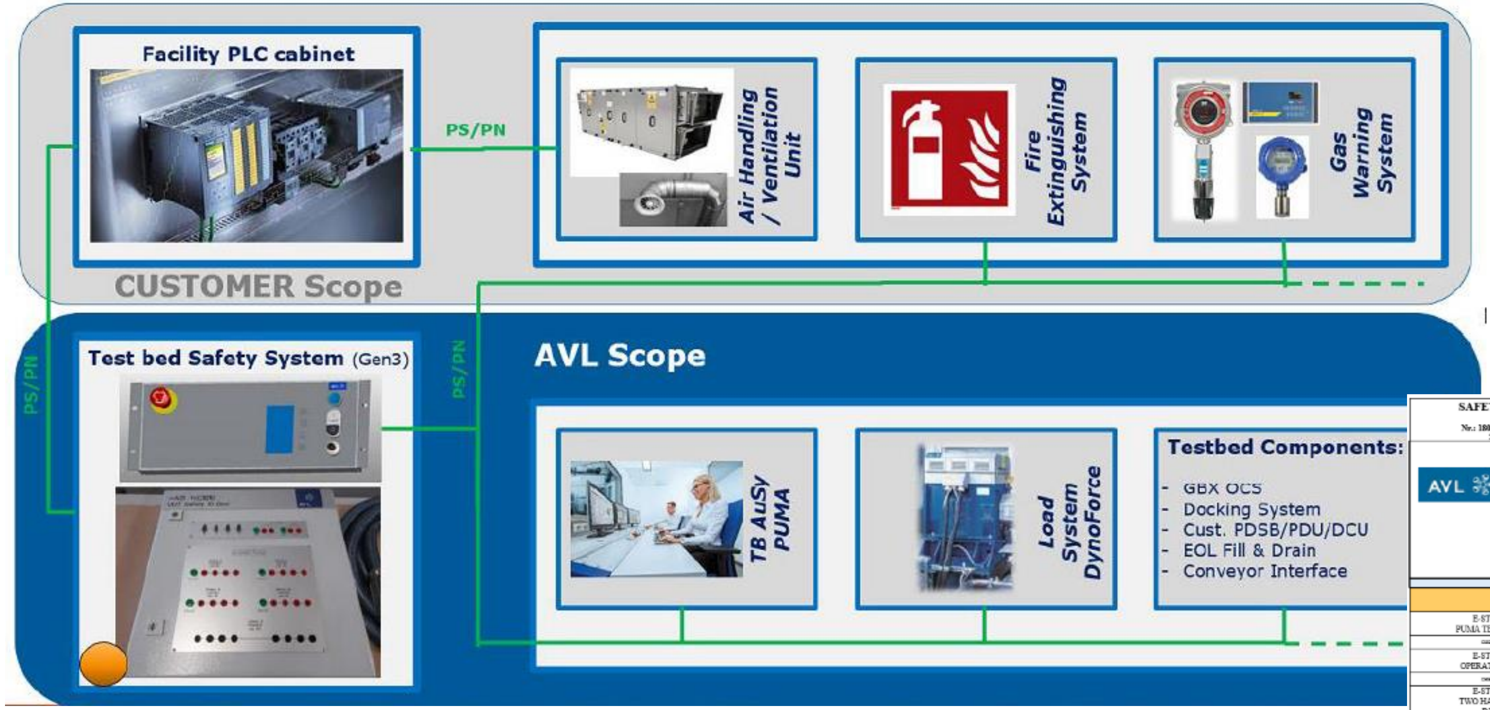
Availability of ventilation in naturally ventilated enclosed spaces is commonly not considered as good.

Safety and control architecture



Simplified layout of the safety and control system architecture.

AVL Safety Safety Generation III - System Topology



Extended Safety Matrix

SAFETY MATRIX
ETB
Nr.: 180-2017 & 181-2017
26.09.2018

BA: 5011702228
Project: CTCI_NB TO92 - 660kW
SerNr.:
Schematic Nr. 180-2017 & 181-2017
OPN: 190799

AVL

Columns (EFFECTS):
1 = Load Dyno STO; 2 = Load Dyno STO (via SS1); 3 = Load Dyno Emergency Stop; 4 = Unit Under Test Power Supply Emergency Switching Off; 5 = Throttle Actuator Emergency Switching Off; 6 = Fuel Consumption Emergency Switching Off; 7 = Fuel Shut Off Valve Closed; 8 = Fuel Pressure Control PRJ Emergency Switching Off; 9 = Conditioning Unit Fuel Temperature Emergency Switching Off; 10 = Control Valves V30, V50, V650 & V390 Emergency Power Off; 11 = Flow Sensor F310 Emergency Power Off; 12 = Coolant Emergency Switching Off; PLC: 13 = Charge Air Conditioning Unit 400VAC & 24VDC Emergency Switching Off; 14 = Coolant Conditioning Filling Pump and Purging Valve Emergency Switching Off; 15 = Coolant Conditioning Circulation Pump & Valves (Power Supply 24VDC +CS & +TR) Emergency Switching Off; 16 = COMPRESSED AIR MAINTENANCE DEVICE DRAIN VALVE TEST XXX OPEN; 17 = Shaft Support stop movements; 18 = Safety Bolts stop movements; 19 = HYDRAULIC DOCKING SYSTEM Hydraulic Pump Emergency Switching Off; 20 = HYDRAULIC DOCKING SYSTEM VENTING VALVE 1 (V-554-B) OPEN; 21 = HYDRAULIC DOCKING SYSTEM VENTING VALVE 2 (V-555-B) OPEN; 22 = HYDRAULIC DOCKING SYSTEM 3-WAY VALVE (V-553) CLOSE (MIDDLE POSITION); 23 = HYDRAULIC DOCKING SYSTEM CHECK VENTING VALVE 1 (V-554-B) WITH PRESSURE SENSOR; 24 = HYDRAULIC DOCKING SYSTEM CHECK VENTING VALVE 2 (V-555-B) WITH PRESSURE SENSOR

CAUSES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
General																								
E-STOP BUTTON 1 PUMA TEST SYSTEM DESK			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
CHECK STATUS ON SITE																								
E-STOP BUTTON 2 OPERATOR PANEL +HMI			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
CHECK STATUS ON SITE																								
E-STOP BUTTON 3 TWO HAND PANEL +THC IN TESTCELL			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
CHECK STATUS ON SITE																								
E-STOP BUTTON 4 INSIDE TEST CELL AT OPERATOR DOOR			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
CHECK STATUS ON SITE																								
E-STOP BUTTON 5 INSIDE TEST CELL AT LOADING DOOR			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
CHECK STATUS ON SITE																								
Watchdog Automation System (Puma)			X	X	X	X	X	X	X	X	X	X	X(3)	X(3)	X(3)	X(3)	X(3)	X(3)	X(3)	X(3)	X(3)	X(3)		
CHECK STATUS ON SITE																								
Shaft Cover Switch		X		X										X										
CHECK STATUS ON SITE																								

Conclusion

Hydrogen is becoming the common denominator across various mobility applications and therefore needs to be considered in new testing infrastructures

Evolving standards and regulations require expertise and experience to plan the infrastructure changes efficiently

AVL as partner on your side can support from the risk assessment to complete test bed solutions to support your transformation

Test bed transformations are possible with approved modules for fuel cell & hydrogen ICE applications

Contact

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Let’s transform the future together