75 1948 2023 VALUES. CREATE. FUTURE.

Pilz Company introduction
Safety & Automation for Hydrogen

Armin Glaser

PILZ
THE SPIRIT OF SAFETY

Company facts

100 %
family-run, medium-sized company

Financially independent company

Fast, independent decision-making

Long-term corporate success comes before short-term success goals

Profits are reinvested, guaranteeing further growth

Global player

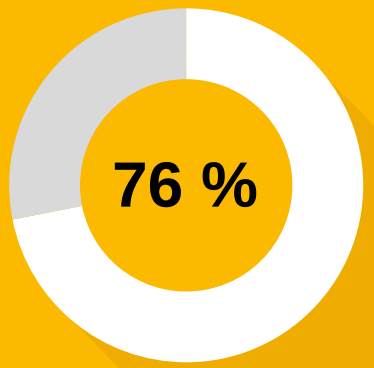
Our company figures

Founded in **1948** as a glass-blowing business

Headquarters in **Ostfildern**

403 m. € turnover

Export



42 subsidiaries

2500 employees

R+D ratio **17 %**

Your partner for safe automation

Sensor technology

Relays

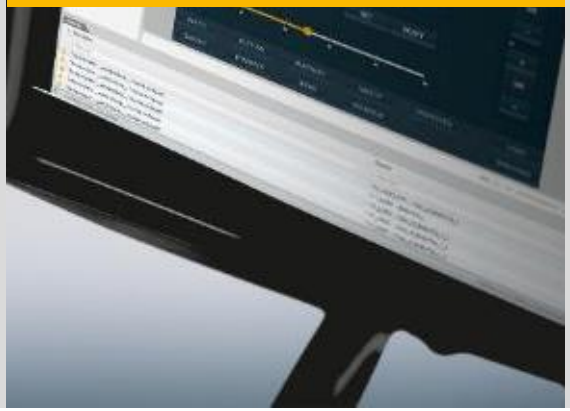
Small controllers

Controllers

Operating and monitoring

Drive technology

Software



Services

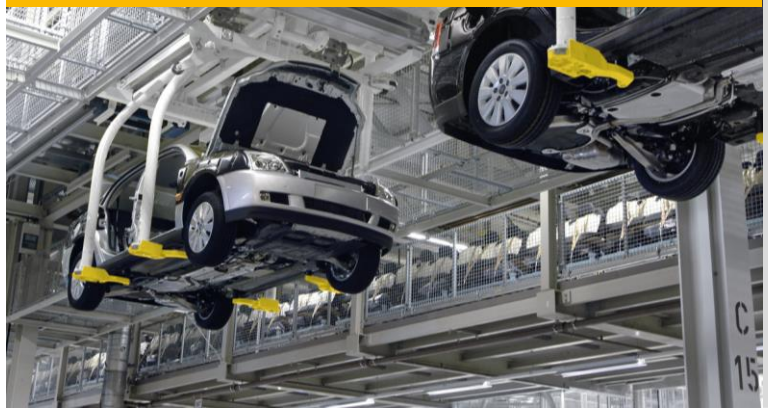
At home in every industry

Packaging technology

Machine tools

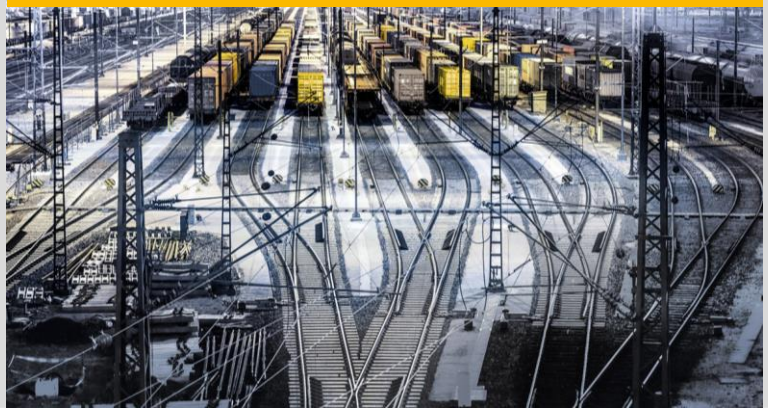
Food industry

Automotive industry

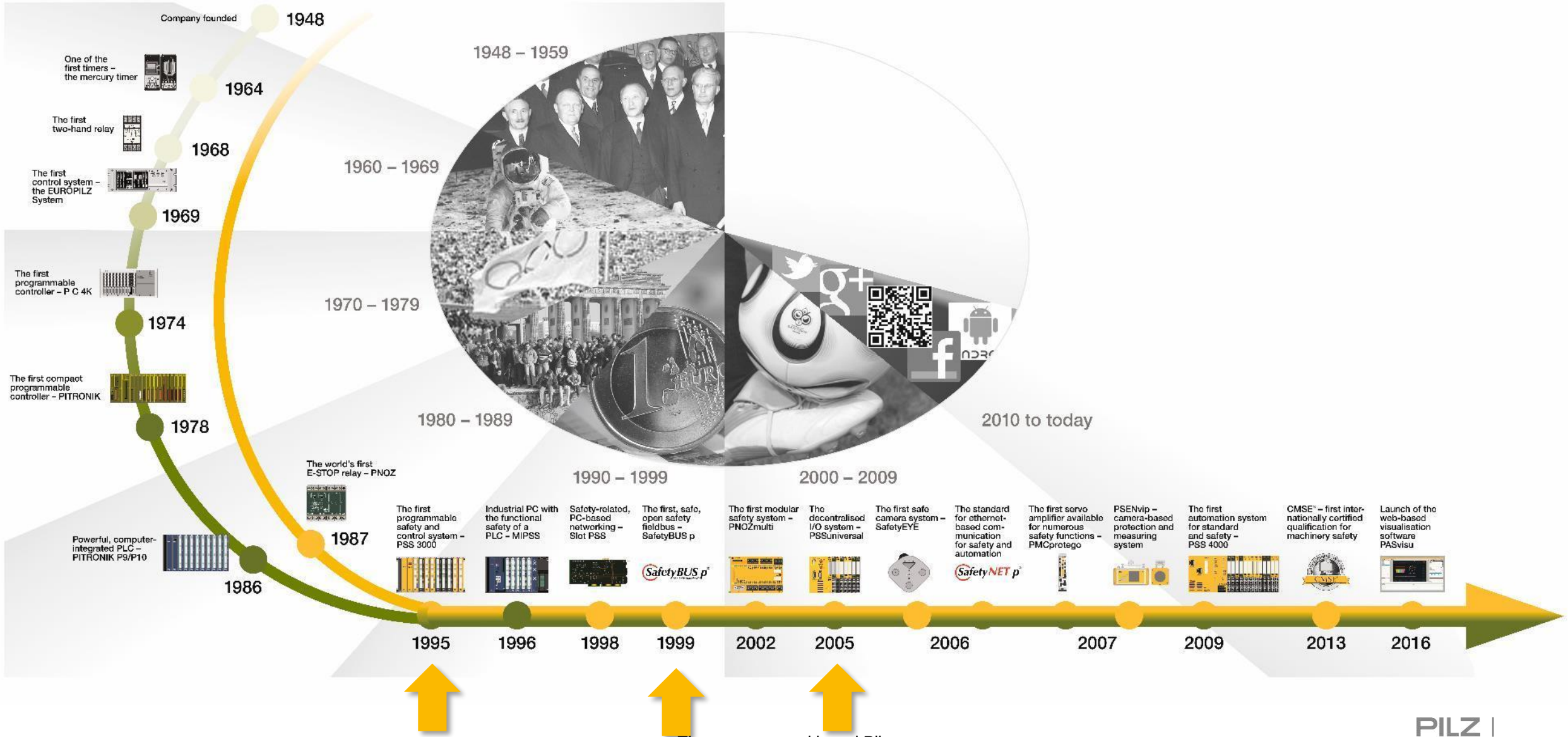


Robotics

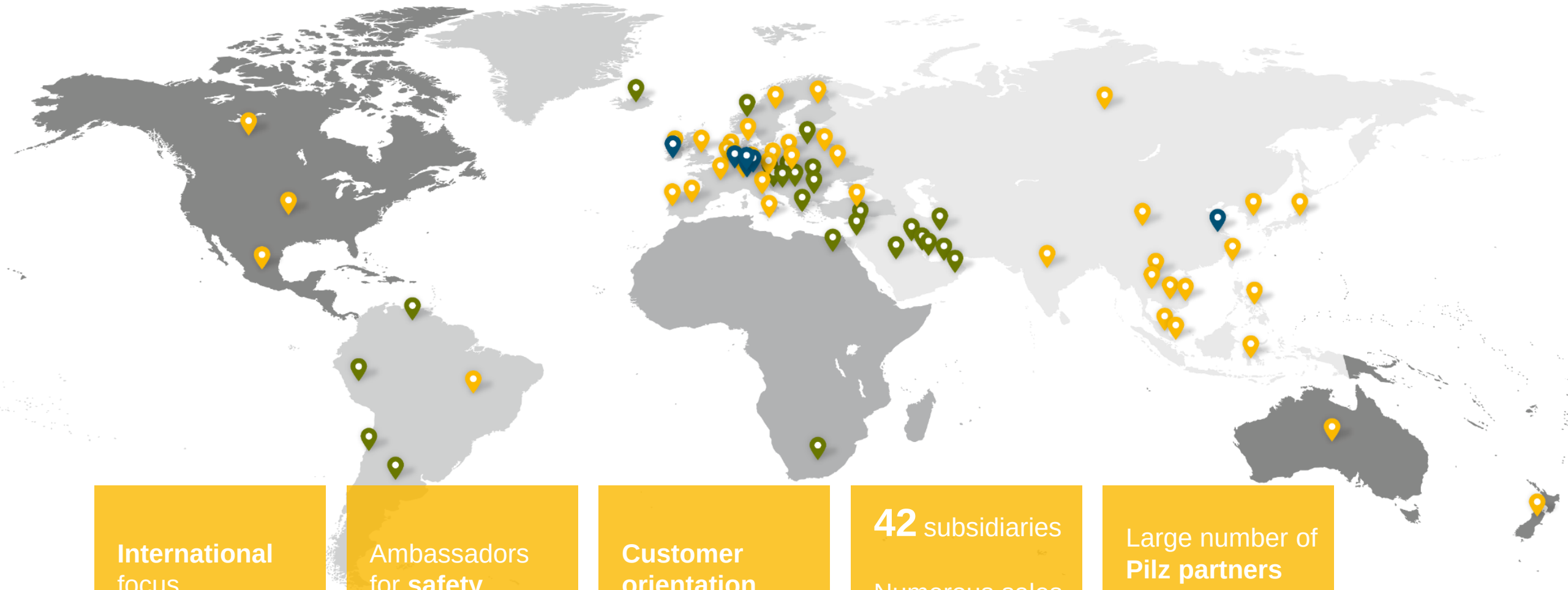
Railway technology



Pilz Innovations in History



Pilz worldwide



International focus

Ambassadors for **safety**

Customer orientation

42 subsidiaries

Numerous sales partners

Large number of **Pilz partners** worldwide

Safety expert

Safety is our **core competency**

Protection objective Global safety

Involvement in around **50 standards committees** worldwide

Hydrogen

PILZ
THE SPIRIT OF SAFETY

2. SUMMARY OVERVIEW OF THE NATIONAL HYDROGEN STRATEGIES[3]

The table 2 below aims to summarise the differing objectives and sectoral priorities of the published national hydrogen strategies.

CATEGORY	ASIA			EUROPE								LAC	NORTH AMERICA
	Australia	Japan	South Korea	EU	France	Germany	Hungary	Netherlands	Norway	Portugal	Spain	Chile	Canada
Strategy contains timeline for market development with targets	●	●	●	●	●	●	●	●	○	●	●	●	●
Strategy contains hydrogen cost targets	●	●	●	○	○	○	○	○	○	○	○	●	●
Strategy includes measures to support H2 development													
Direct investments	●	●	●	●	●	●	○	●	●	●	●	●	●
Other economic and financial mechanisms	●	●	●	●	●	●	●	●	●	●	●	●	●
Legislative and regulatory measures	●	●	●	●	●	●	●	●	●	●	●	●	●
Standardisation strategy and priorities	●	●	●	●	●	●	●	●	●	●	●	●	●
Research & development initiatives	●	●	●	●	●	●	●	●	●	●	●	●	●
International strategy	●	●	●	●	●	●	●	●	●	●	●	●	●
Strategy addresses social issues for H2 development	●	●	●	○	●	●	○	●	●	●	●	●	●
Strategy includes review and update	●	○	○	○	○	●	○	○	●	●	●	●	○
Strategy's H2 target source by 2030	Clean	Fossil-based with CCS	From natural gas	Low carbon	Low-carbon & fossil based	Carbon-free	Low carbon & carbon free	Blue & Green	Clean	Green	Renewable	Green	Low carbon intensity
Strategy's H2 target source by 2050	Clean	CO_2-free	Eco-friendly CO_2-free	Clean / Renewable	Low-carbon	Renewable	Low carbon & carbon free	Green	Clean	Green	Renewable	Green	Low carbon intensity
Import / Self-reliance / Export	Export; Self-reliance	Import	Import; Export (tech)	Depends on Member States	Export	Import; Export (tech)	Self-reliance	Import to export H2 (EU hub)	Self-reliance	Self-reliance; Export	Self-reliance; Export	Self-reliance; Export	Self-reliance; Export
MAIN GOALS / DRIVERS													
Decarbonisation	Lower	Immediate	Lower	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate
Diversify energy supply	Lower	Immediate	Long term	Lower	Lower	Immediate	Immediate	Immediate	Lower	Immediate	Immediate	Lower	Immediate
Foster economic growth	Immediate	Immediate	Immediate	Lower	Immediate	Immediate	Lower	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate
Integration of renewables	Lower	Lower	Long term	Immediate	Lower	Immediate	Lower	Immediate	Lower	Immediate	Immediate	Immediate	Immediate
SECTORAL PRIORITIES													
Heating	Immediate	Immediate	Lower	Lower	Lower	Lower	Immediate	Immediate	Lower	Immediate	Lower	Immediate	Immediate
Industry													
Iron and Steel	Long term	Lower	Lower	Long term	Immediate	Immediate	Long term	Immediate	Lower	Immediate	Lower	Not seen	Immediate
Chemical feedstock	Immediate	Lower	Not seen	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate
Refining	Not seen	Lower	Not seen	Immediate	Immediate	Immediate	Immediate	Immediate	Lower	Immediate	Immediate	Immediate	Immediate
Others (cement, etc.)	Not seen	Not seen	Not seen	Not seen	Immediate	Lower	Long term	Lower	Not seen	Immediate	Lower	Not seen	Immediate
Power													
Power generation	Lower	Immediate	Immediate	Lower	Not seen	Not seen	Lower	Lower	Not seen	Lower	Lower	Not seen	Lower
Back-up services	Lower	Lower	Lower	Lower	Not seen	Not seen	Long term	Lower	Not seen	Lower	Lower	Not seen	Lower
Transport													
Passenger vehicles	Lower	Immediate	Immediate	Lower	Lower	Lower	Long term	Immediate	Lower	Lower	Lower	Long term	Immediate
Medium and heavy duty	Immediate	Long term	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Lower	Immediate	Lower	Immediate	Immediate
Buses	Immediate	Long term	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Lower	Immediate	Lower	Immediate	Immediate
Rail	Lower	Lower	Lower	Immediate	Immediate	Immediate	Lower	Immediate	Not seen	Immediate	Lower	Not seen	Long term
Maritime	Long term	Lower	Lower	Long term	Lower	Long term	Lower	Lower	Immediate	Long term	Lower	Long term	Long term
Aviation	Lower	Lower	Not seen	Long term	Immediate	Long term	Not seen	Lower	Lower	Long term	Lower	Long term	Long term

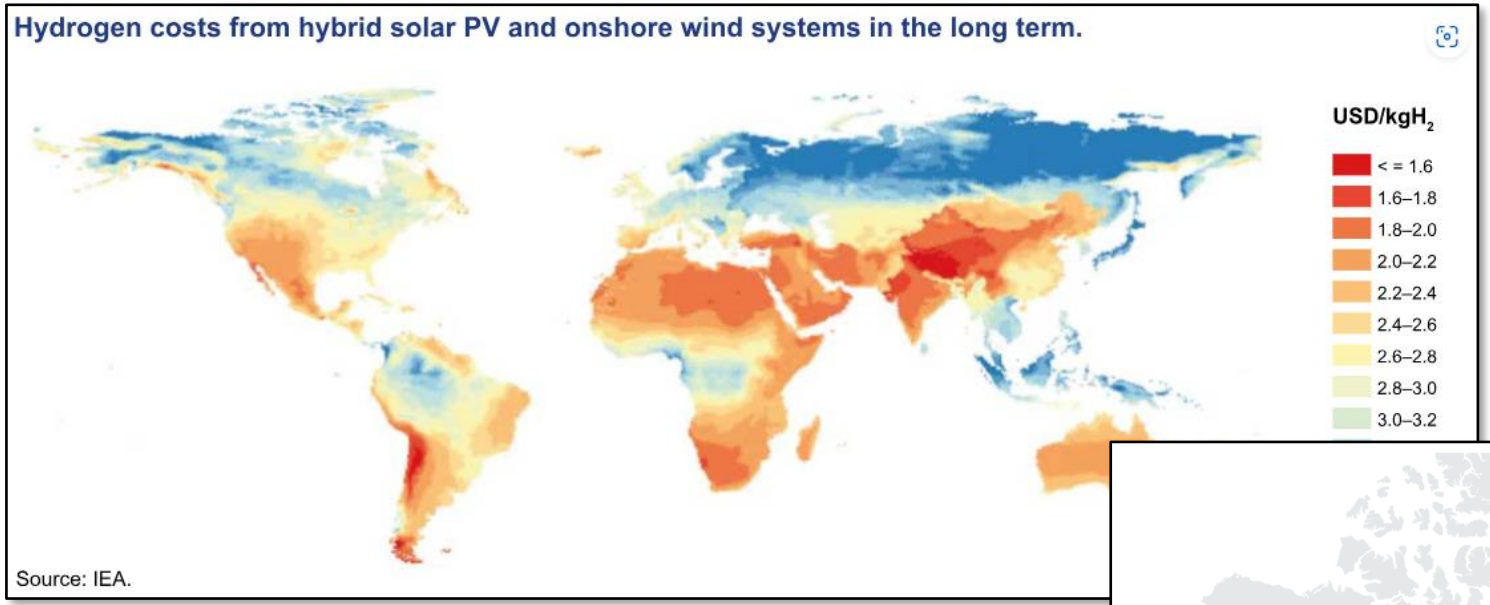
Source: World Energy Council

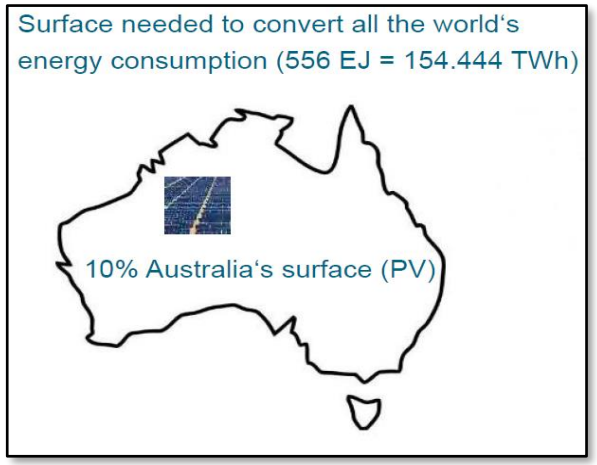
[3] *Methodology: National strategies published until 30th May 2021.*

Strategies content:
● *Detailed* ● *Mentioned* ○ *Not seen*

Goals and sector priorities:
Immediate priority | Long term priority | Lower priority | Not seen

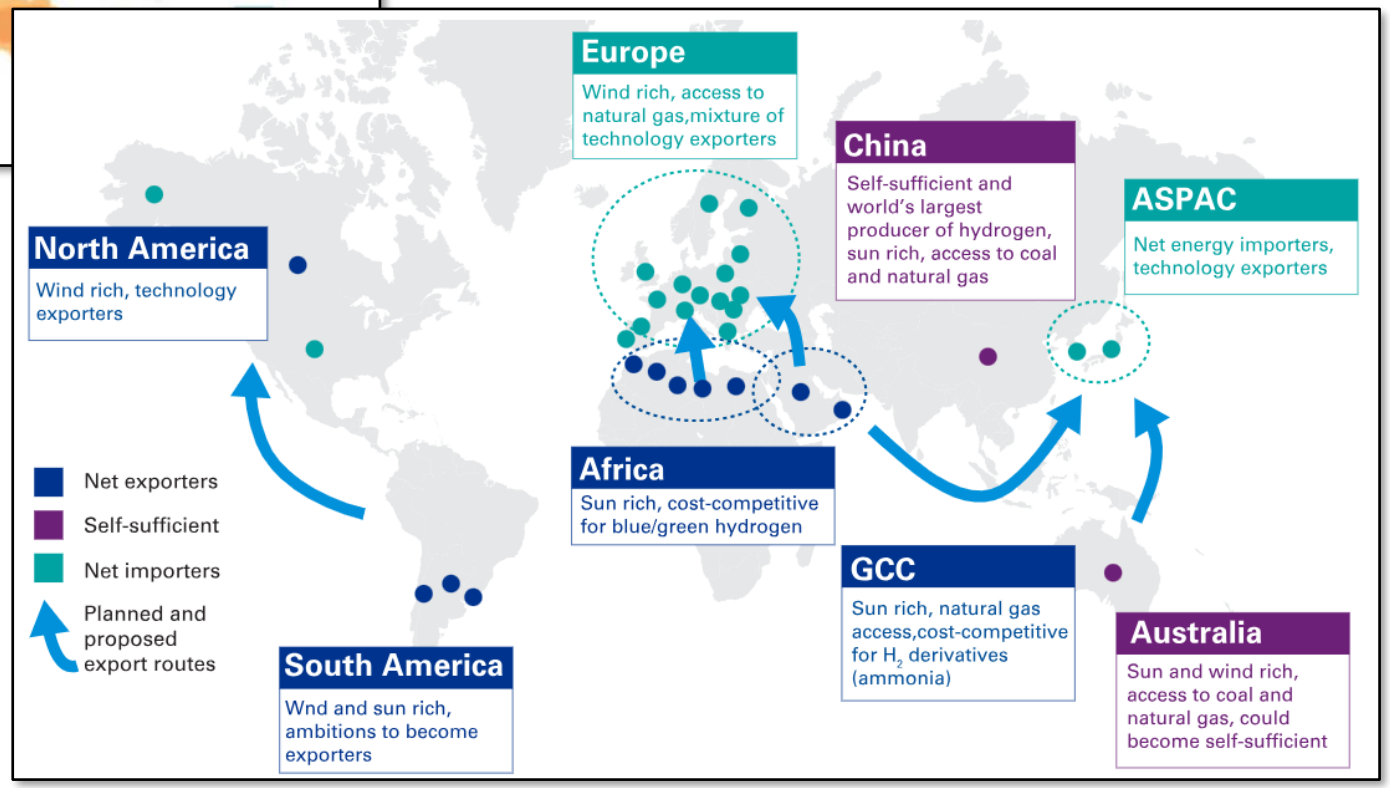
International value streams





KPMG

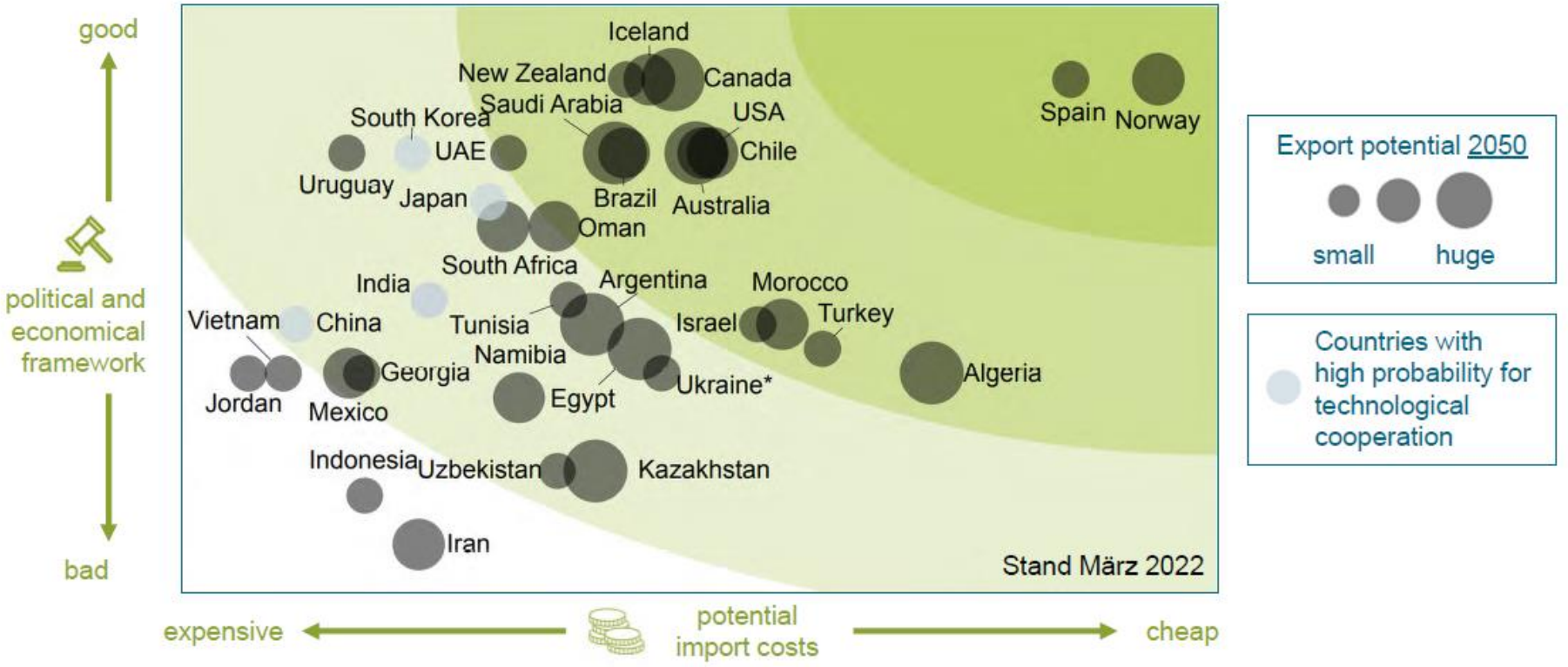
[Geographic hydrogen hotspots - KPMG Global]



International target regions for MOEM

VDMA: perfect fit to the business model of EU machine builders (export technology)

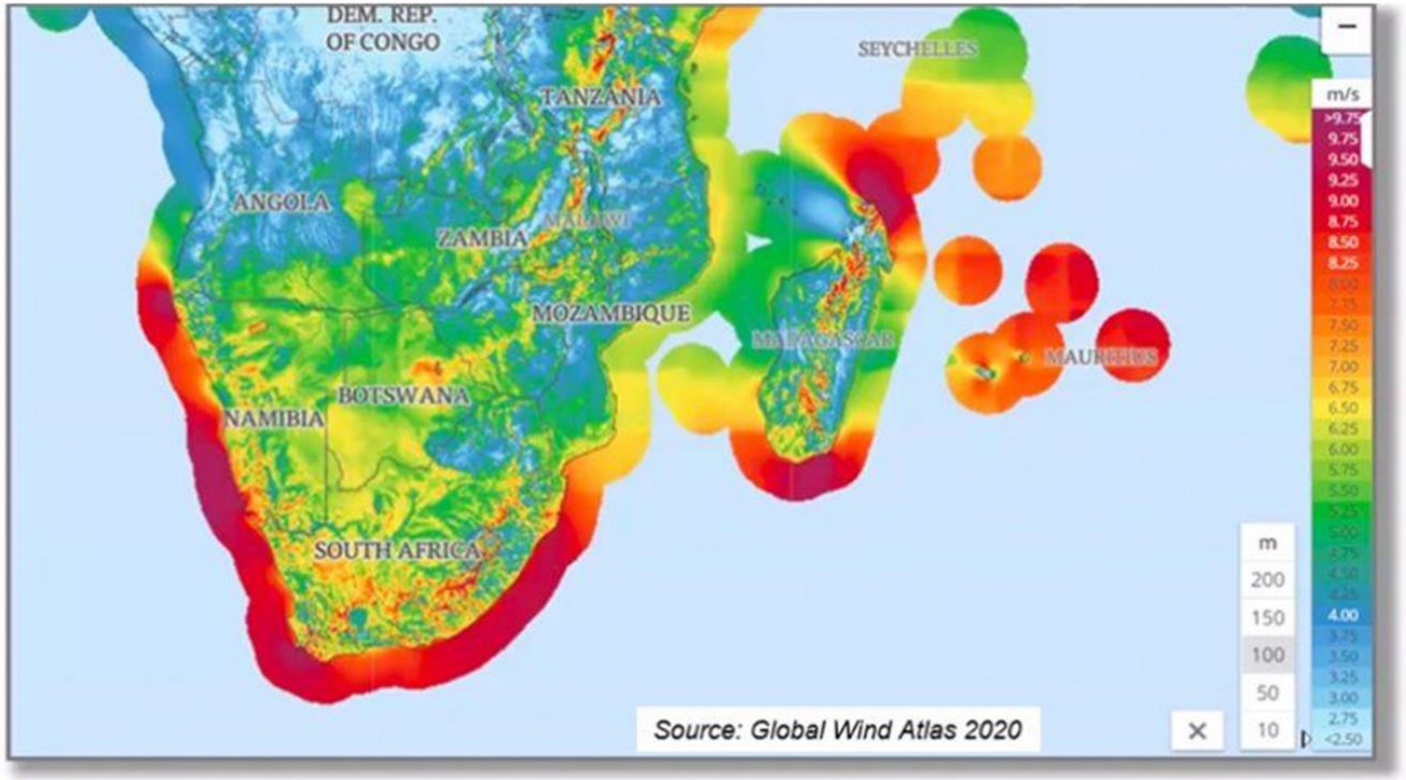
Germany: International cooperation and export potential for green hydrogen in 2030



*prior to the Russian invasion on 24.02.2022

Quelle: Guidehouse (https://guidehouse.com/-/media/www/site/insights/energy/2022/transport-options-for-covering-germanys-green-hydrogen-demand.pdf)

“South Africa’s solar in the Northern Cape has the potential to not only generate energy for the domestic economy but also to export this clean energy through the West Coast Ports”



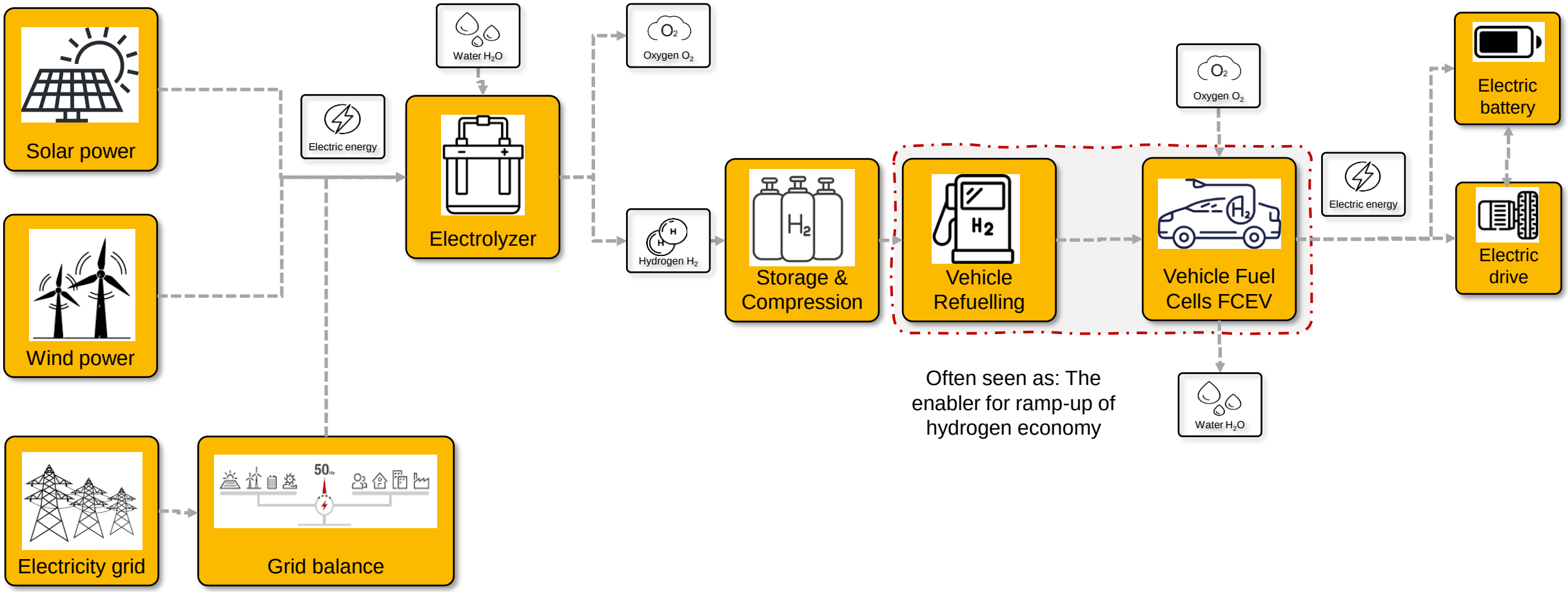
The governments of South Africa, the Netherlands and Denmark have launched a $1 billion greenhydrogen fund. South Africa President Ramaphosa: "the investments in renewable energy would be beneficial to all three countries."

Dutch Prime Minister Mark Rutte: “With its enormous renewable resources, South Africa is uniquely positioned to become a key player in the global hydrogen market, and the Netherlands is equally well-positioned to become a strategic partner. First as a partner for local development in the fields of renewable energy, hydrogen and infrastructure, and also as a hub for hydrogen imports”.
Danish Prime Minister Mette Frederiksen: “Denmark is, of course, very proud to be a partner in South Africa's just energy transition. We will contribute with around R3.2 billion to improve supplies of green power and to strengthen the skills, the employment and the local development

16.10.2023

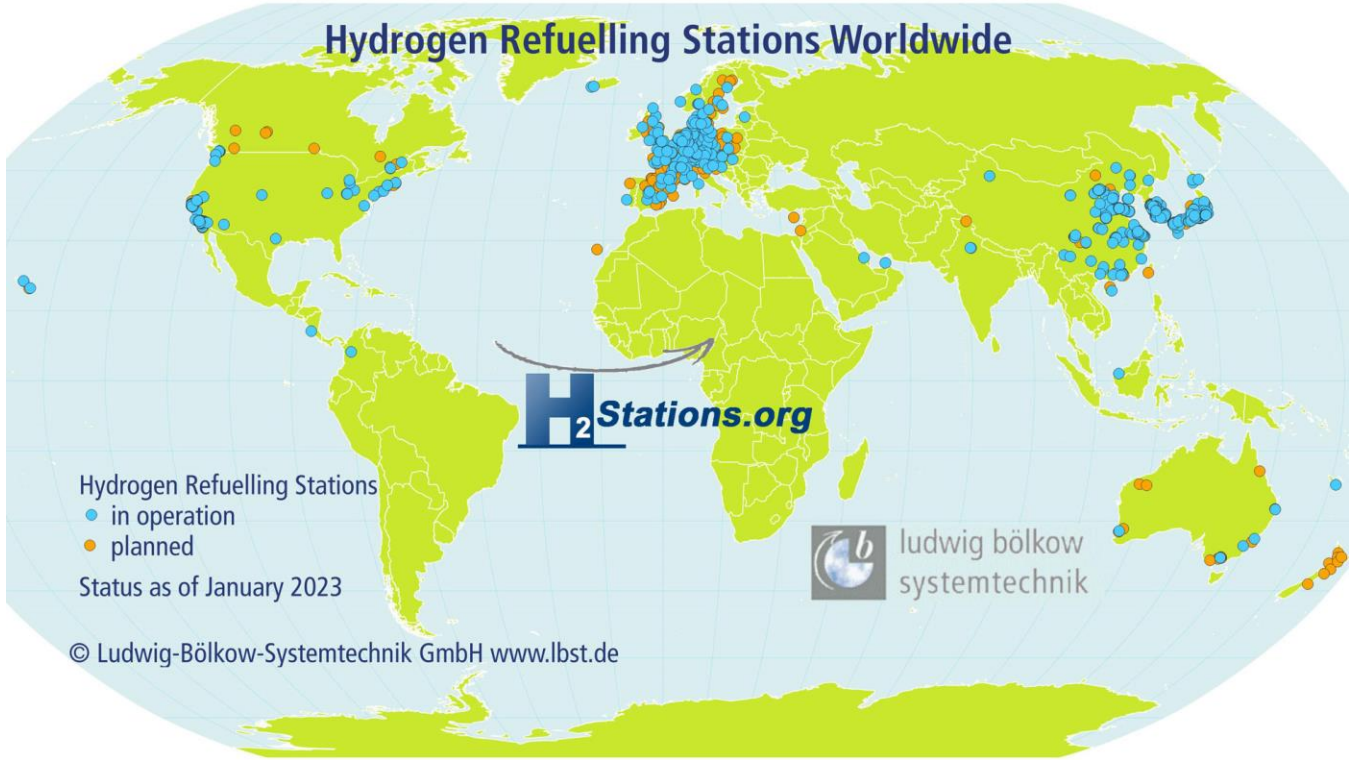
E2H Electricity to Hydrogen

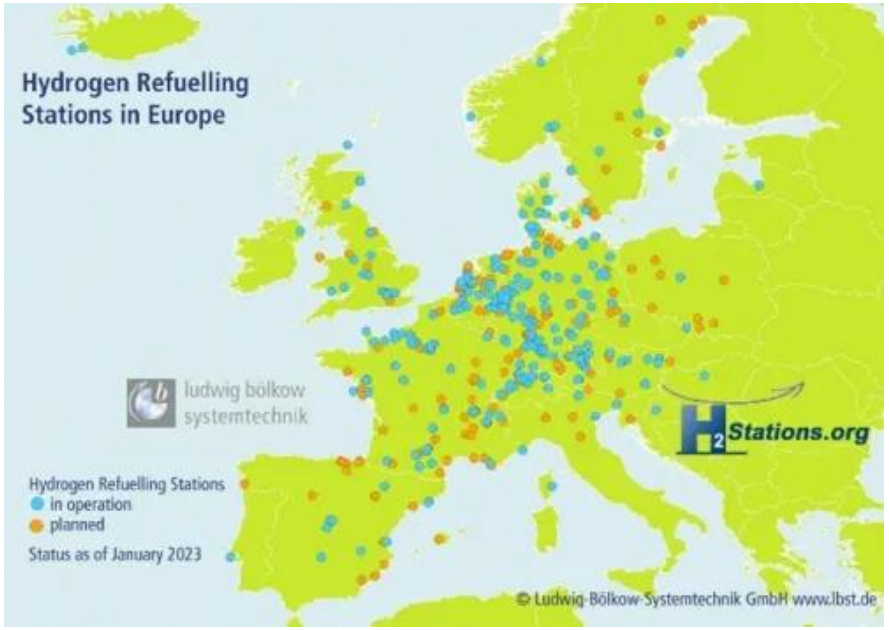
H2E Hydrogen to Electricity

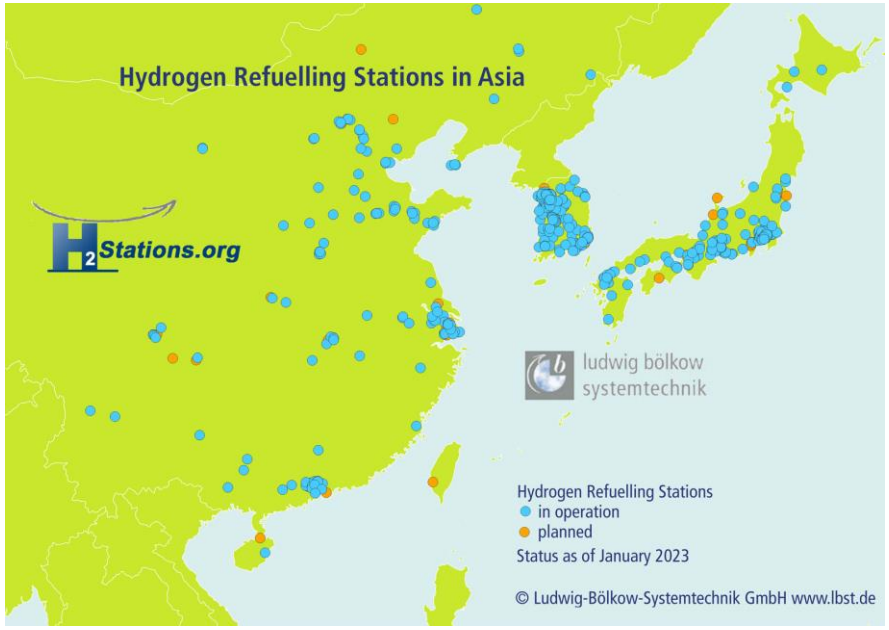


- Hydrogen can be made without any fossil fuels in the production and delivery of the fuel, as it is made on-site. Renewable Energy and excess electricity from the grid is used, along with water to generate hydrogen and oxygen gas via the electrolyser
- The hydrogen gas is stored and then used to refuel fuel cell electric vehicles.

H2 Refueling stations worldwide

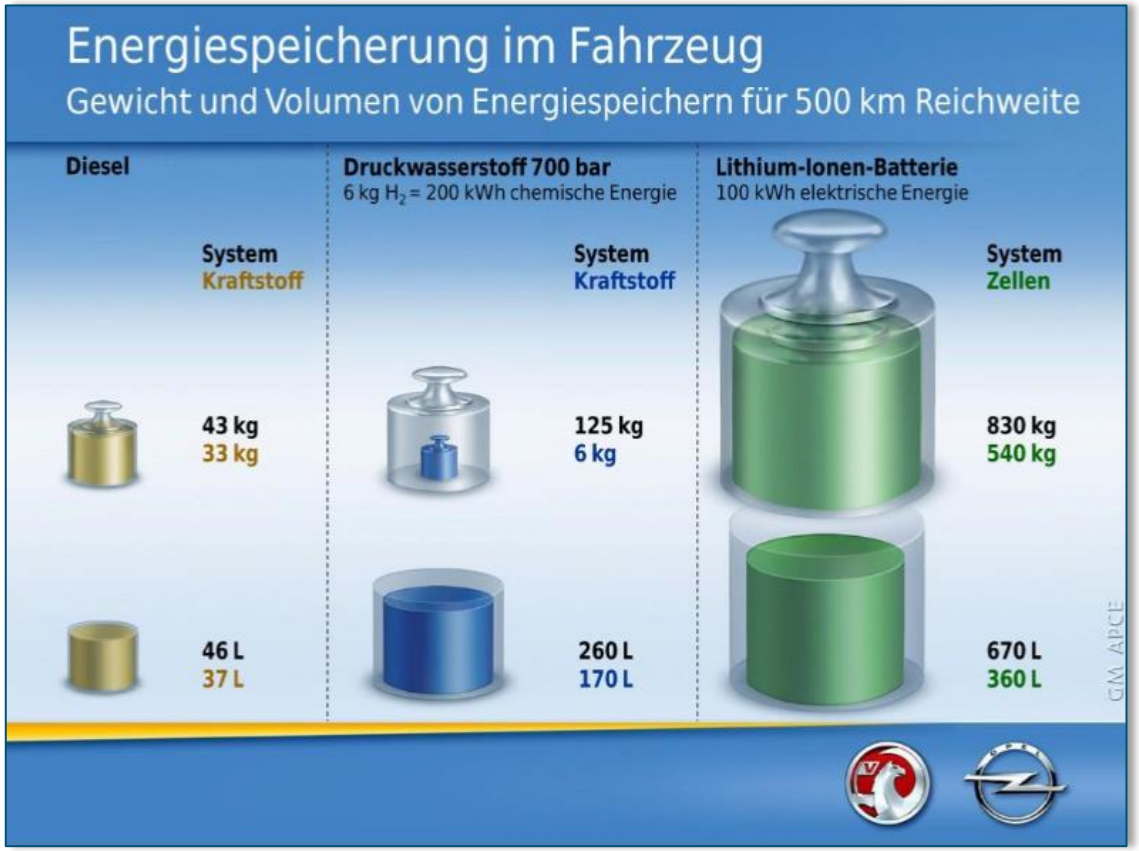


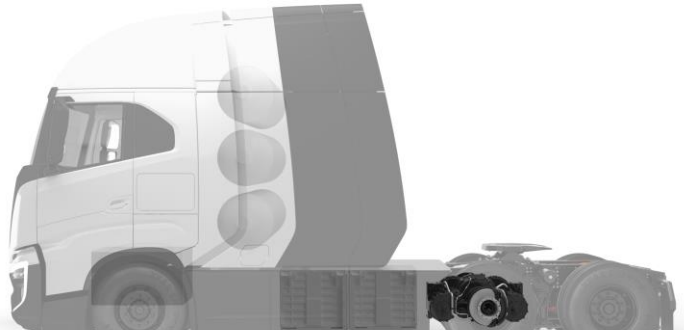




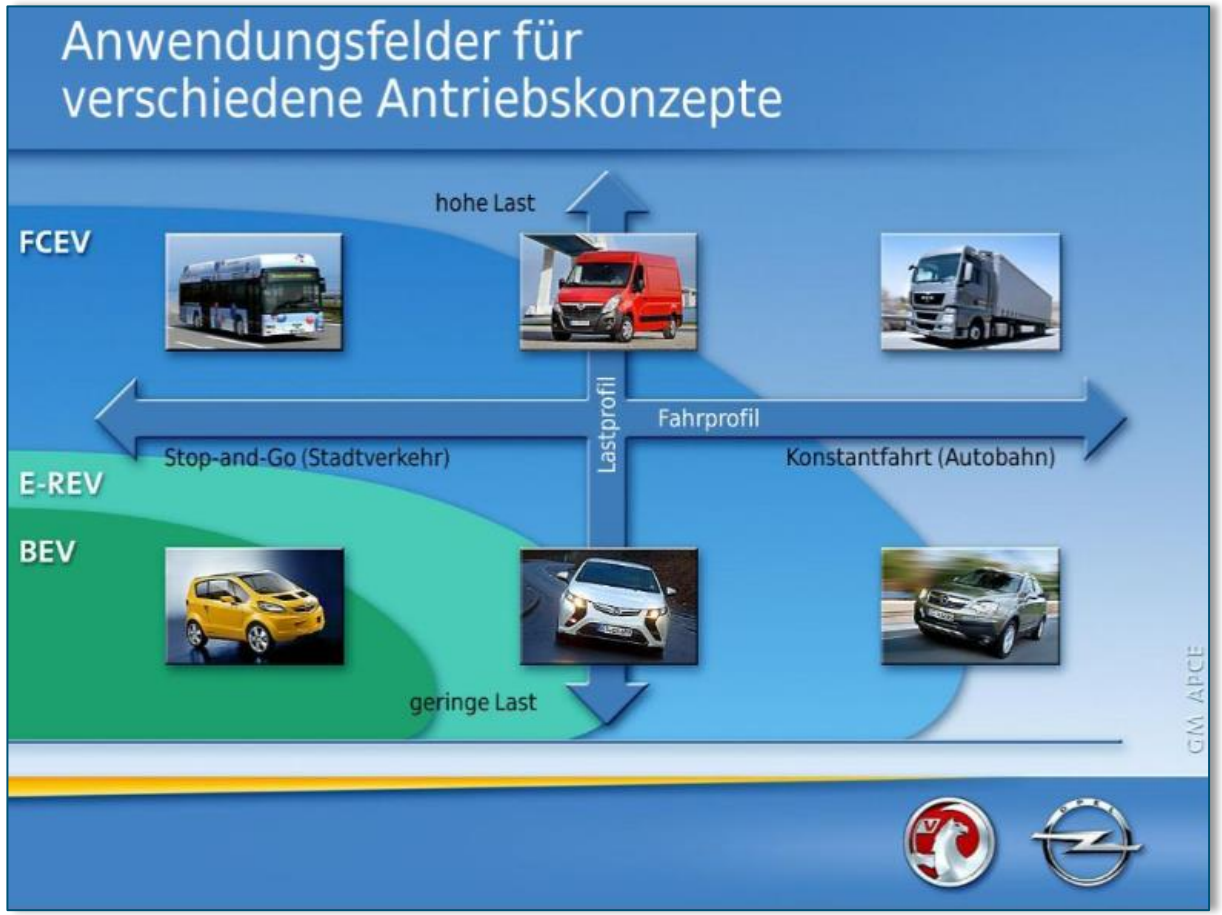
[Press Release 2023: Another record addition of European hydrogen refuelling stations in 2022 - H2Stations.org]

Battery vs. Hydrogen in vehicles





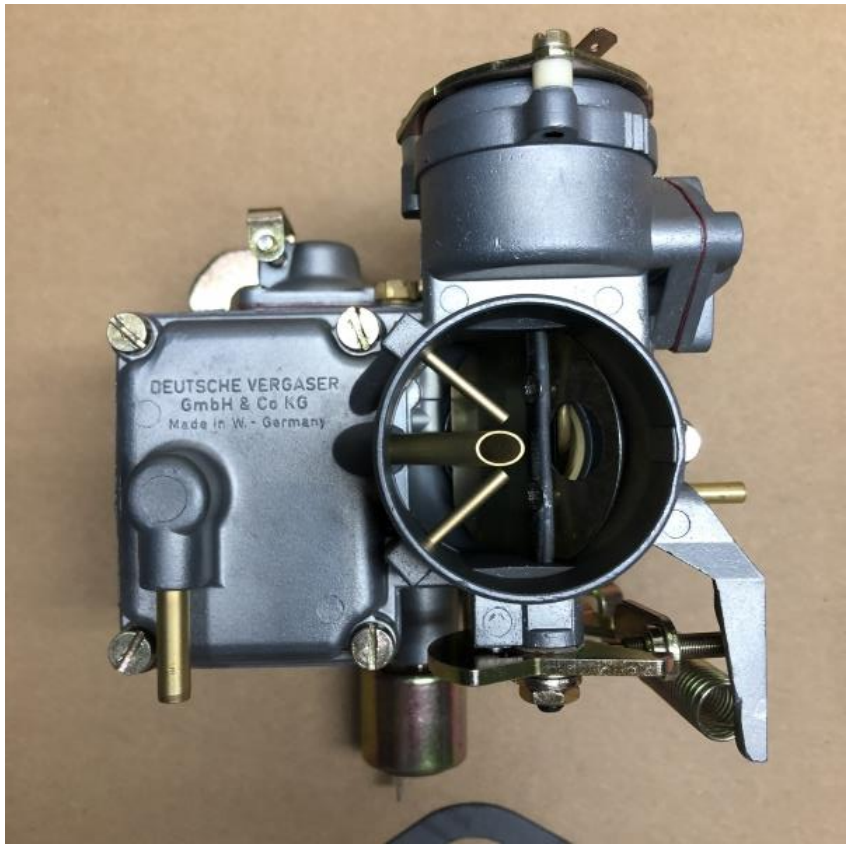
- Limited storage density for batteries in the future
- purely battery-electric drive only makes sense for small vehicles with a short range
- Source: [Wasserstoff als Kraftstoff (yumpu.com)]

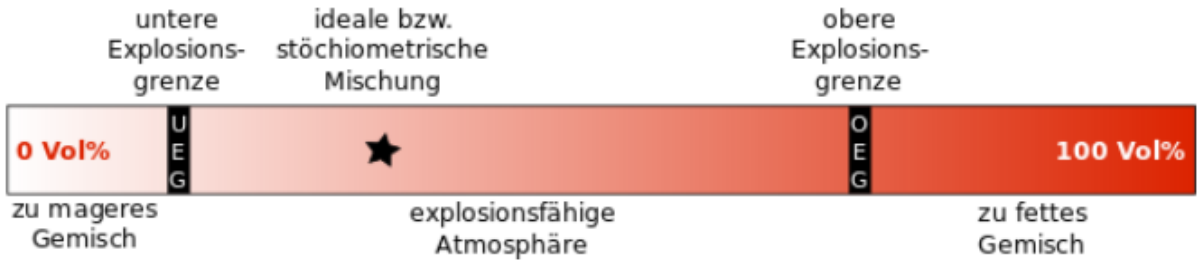


Hydrogen & Safety

PILZ
THE SPIRIT OF SAFETY

Gaseous Concentrations ignitable mixtures in the carburettor





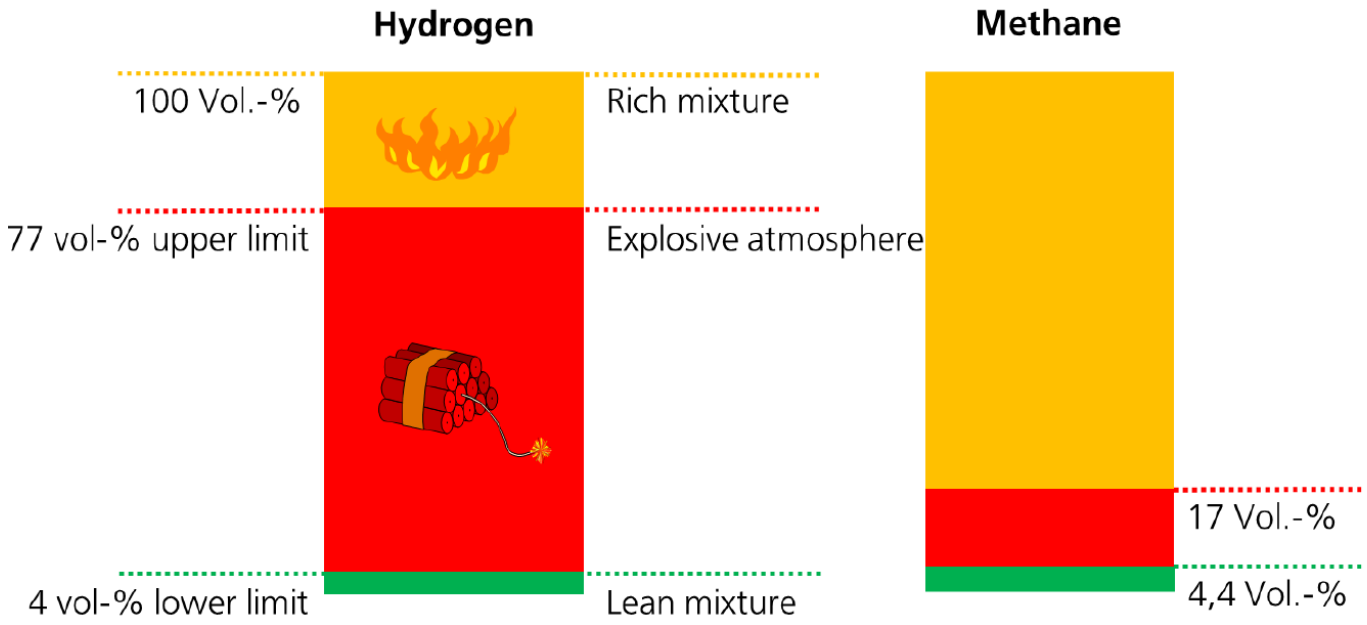
- Lean mixture
- rich mixture

Hazardous Concentrations Hydrogen vs. Methane

Flagship Project TransHyDE Verbund Sichere Infrastruktur

Federal Ministry of Education and Research

Safety Challenge: Explosion Hazard



TransHyDE-Verbund Sichere Infrastruktur – Prof. Jürgen Wöllenstein – 30.11.2022 2

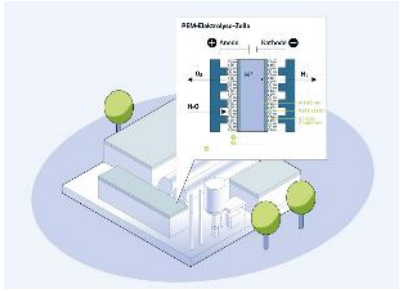
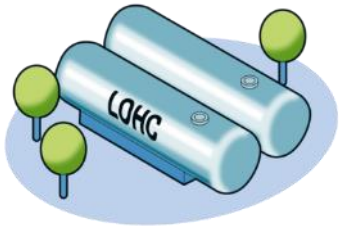
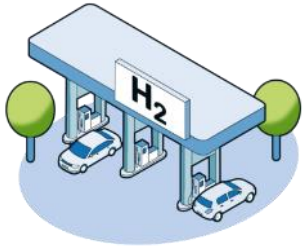
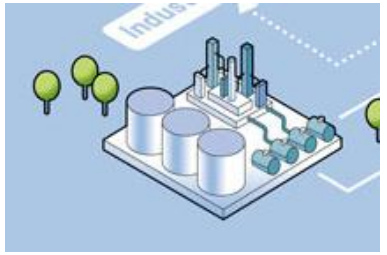
- Explosionsgrenzen sind Grenzen des sogenannten „Explosionsbereiches“. Die untere Explosionsgrenze (UEG) bzw. die obere Explosionsgrenze (OEG) sind der untere bzw. obere Grenzwert der Konzentration (Stoffmengenanteil) eines brennbaren Stoffes in einem Gemisch von Gasen, Dämpfen, Nebeln und/oder Stäuben, in dem sich nach dem Zünden eine von der Zündquelle unabhängige Flamme gerade nicht mehr selbstständig fortpflanzen kann
- Explosionsgrenze – Wikipedia

- Yellow: Concentration is too high for flame to spread explosively
- Red: Flame spread "explosive"

- Explosive concentration range H2 is larger than methane

- Hydrogen (almost) always **explodes**
- Methane (almost) always **burns**

The Hydrogen process

	H_2-Generation	H_2-Transport	H_2-Storage	H_2-Fuel Stations	H_2-Consumers
					
Large scale industries	Large scale H_2 production with Windfarms, Electrolysers, Powerplants, Hydroelectric,	Large scale H_2 converters NH_3, LOHCs Pipelines Ships, Carriers	Large scale compressors Tank farms for LH_2 Liquid Hydrogen, Compressed Gaseous Hydrogen CGH_2		Large scale consumers: chemical industries, steel plants
Special Machines	AWE, AEM, PEM Electrolysers Reformers LOHC (liquid-organic hydrogen carrier)	Focus area is „container based“ small plants in a box = machine	Gas refueling Fuel stations Mixture stations		Burners, Combustion Engines/Generators which use hydrogen as a fuel

Automation & Safety requirements

	H_2-Generation	H_2-Transport	H_2-Storage	H_2-Fuel Stations	H_2-Consumers
Application types	AWE, AEM, PEM Electrolysers Reformers Release H_2 from carrier NH3 / LOHC (liquid-organic hydrogen carrier)		LOHC (liquid-organic hydrogen carrier)	Gas refueling Mixture stations	Burners, Combustion FuelCells, Gas Engines Absorb H_2 in carrier NH3 / LOHC (liquid-organic hydrogen carrier
Functional safety requirements	Pressure monitoring Gas detection (monitoring of room/enclosure) Temperature monitoring Voltage monitoring Current monitoring Safety Gate Systems for containers access management (ATEX)	leakage detection tightness monitoring flow monitoring	leakage detection tightness monitoring pressure monitoring	Tightness monitoring Gas detection (monitoring of room/enclosure) Pressure monitoring Gas mixture monitoring (H_2-ratio) Access management E-Stops (ATEX)	Temperature monitoring Gas detection (monitoring of room/enclosure) Flame monitoring Gas mixture monitoring (H_2-ratio) Combustion sequence Access management E-Stops
Automation requirements	Process quality (gas drying) avoiding oxyhydrogen gas (explosive) Closed loop controls, analogue value processing Usual process control functions			Closed loop controls, analogue value processing Usual process control fun ctions	Fuel cells: Gas purity (avoidance of contamination) Closed loop controls, analogue value processing Usual process control fun ctions

Hydrogen refueling stations

High tech facilities

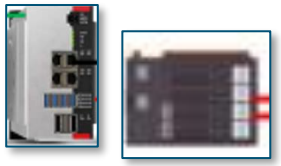
- Storaged always nearby. H2 is easy to compress and it do not increase temperature but decrease.
- In order to fill the H2 fuel into the vehicle. It is needed much higher pressure rather than in storage. That's why we always find a compressor
- It need a cooling area because if not it could be too much hot before going to the compressure…
  - **Temperature and pressure safe monitoring !!!**

1kg H2!!

- https://cmb.tech/

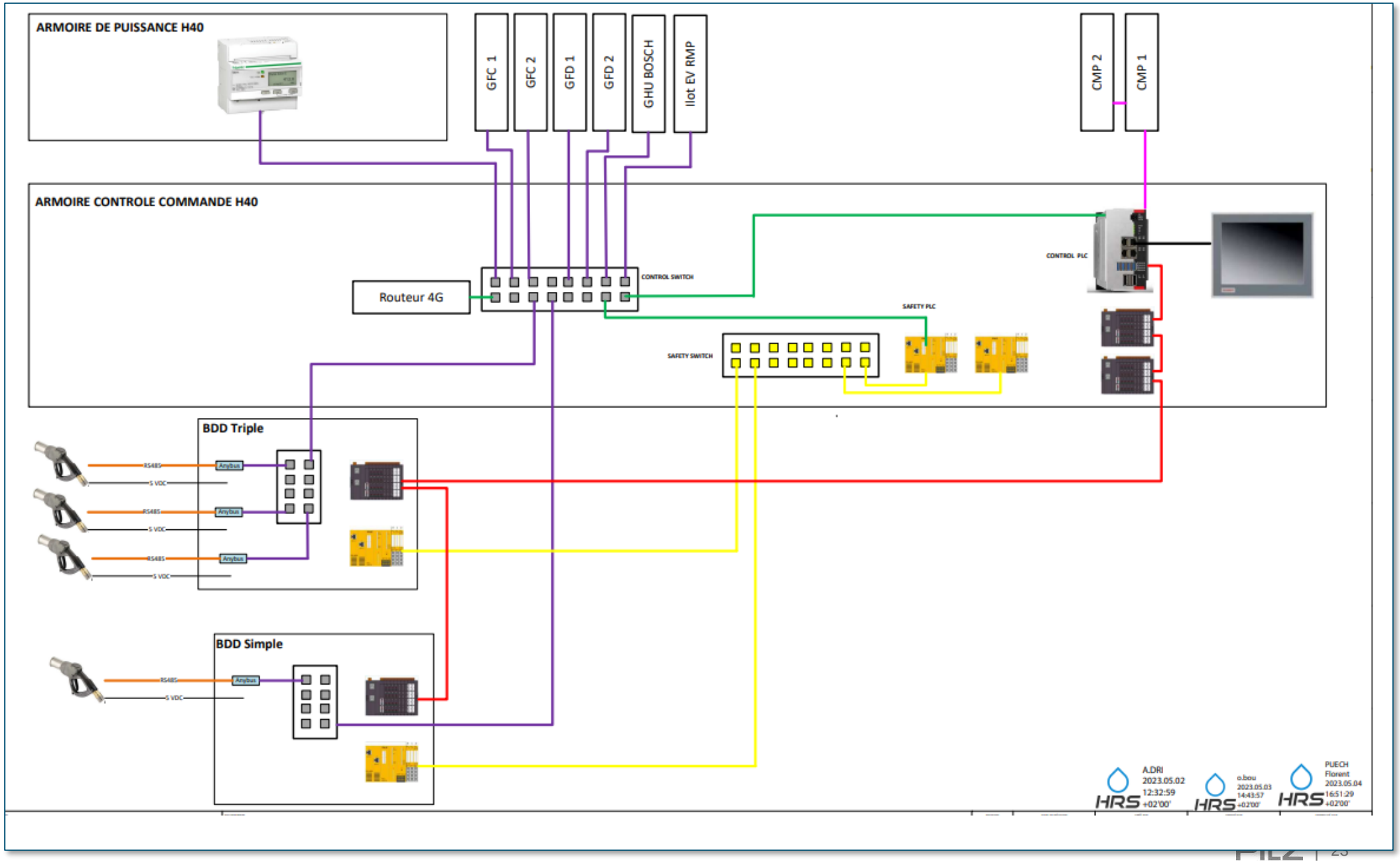
HRS

- Automation: Beckhoff

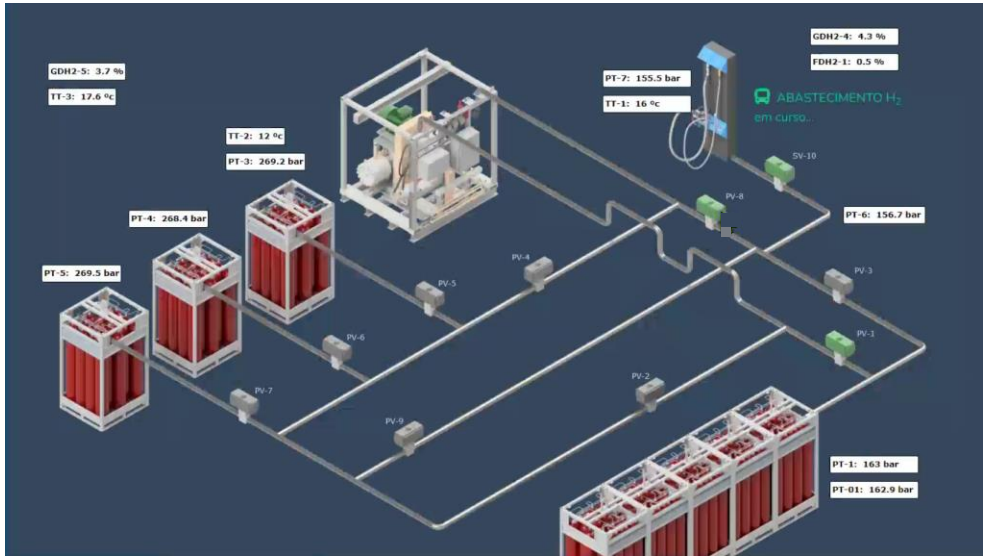


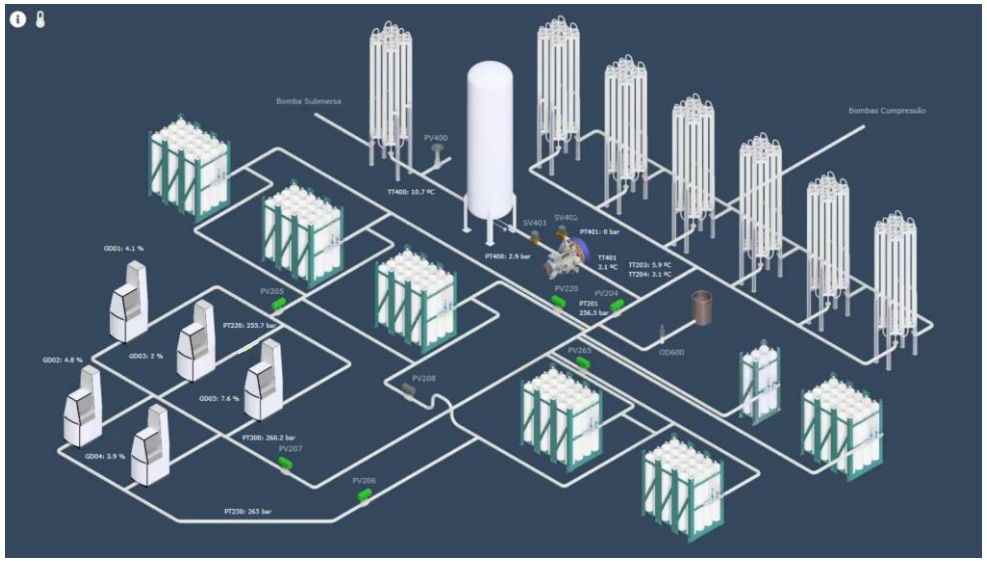
- C6030 Ultra-Kompakt-Industrie-PC

- Safety: Pilz

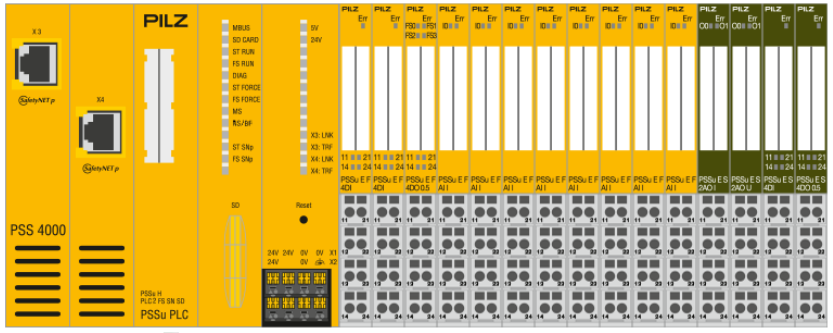


Gas fuel stations





Diagnostics



Gas Detection

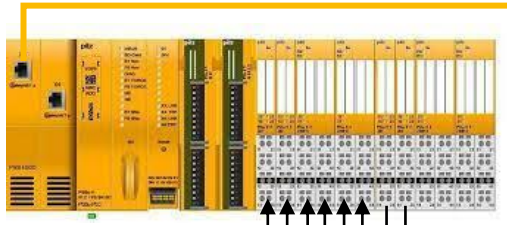
Temperature

Pressure

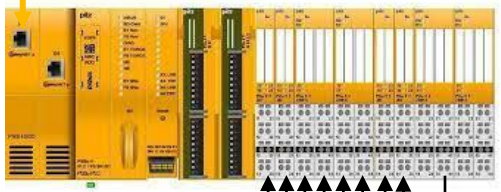
Valves

Hydrogen station

Filling station



SafetyNet communication
to the distribution area



Non ATEX area
Smoke Detector
2NC

ATEX area
Flame detector 1
2NC
Flame detector 2
2NC

Compressor area
Gas leakage
4…20mA

High pressure area
Flame detector 3
2NC
Flame detector 4
2NC

2DO
Input port
Main Safe valve

2DO
Compressor area
Safety Contactor

Filling area
H2 detector (leakage)
4…20mA 1NC
Pressure sensor 750bar
4…20mA
Pressure sensor 300bar
4…20mA
Pressure sensor 300bar + High flow
4…20mA
Temperature sensor 750bar
4…20mA
Temperature sensor 300bar
4…20mA
Temperature sensor 300bar + High flow
4…20mA

2NC

2DO
Filling area
Main Safe valve

Information coming out from HAZOP

- **A safety PLC**
  - managing hydrogen detectors, flame detectors, EIS (emergency stops, temperature sensors, pressure)

- **Actions in case of emergency:**
  - Shutdown (emergency stop button, general installation stop)
  - Closure of the isolation valve for hydrogen sources (main valve)
  - Closing the hydrogen distribution valve (filling station valve)
  - Opening of the vent valves of hydrogen lines

- **Identification and Access Management:**
  - Maintenance operators niv 1 & 2: access to synoptics, leak detections, visual checks, external cleanliness.
  - Maintenance operators niv 3 & 4: level 1 & 2 + access to maintenance mode (manual control), possibility to acquire defects, access to sensor scales in case of replacement, access to changes in process parameters (no modification of safety thresholds)

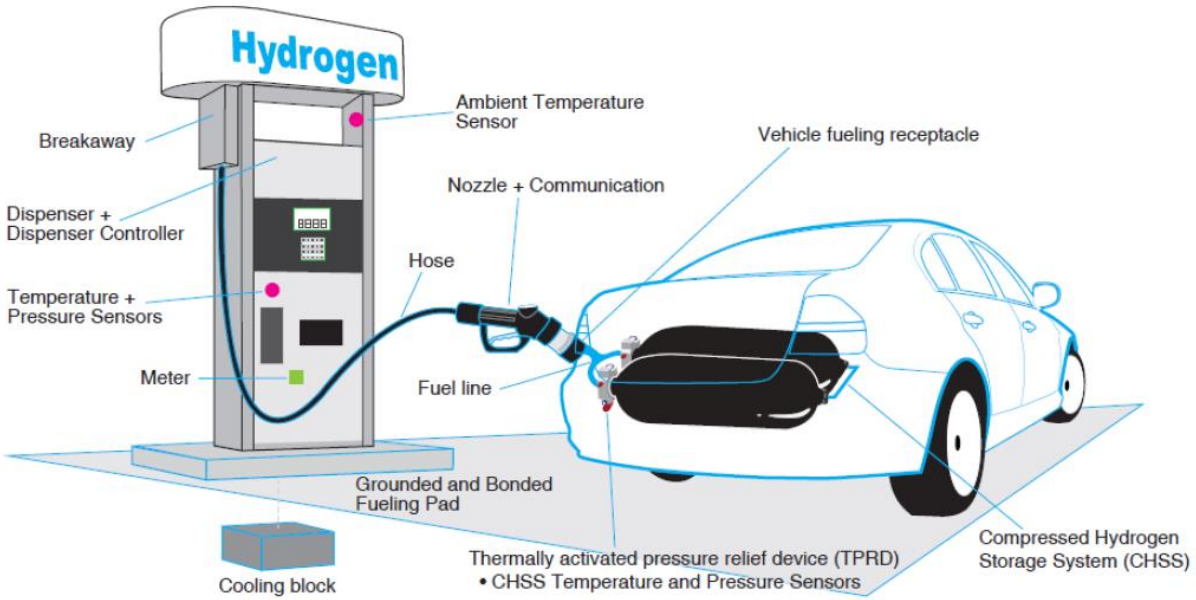


Figure 3 Hydrogen Fueling Components Overview (courtesy of ISO 19880-1)

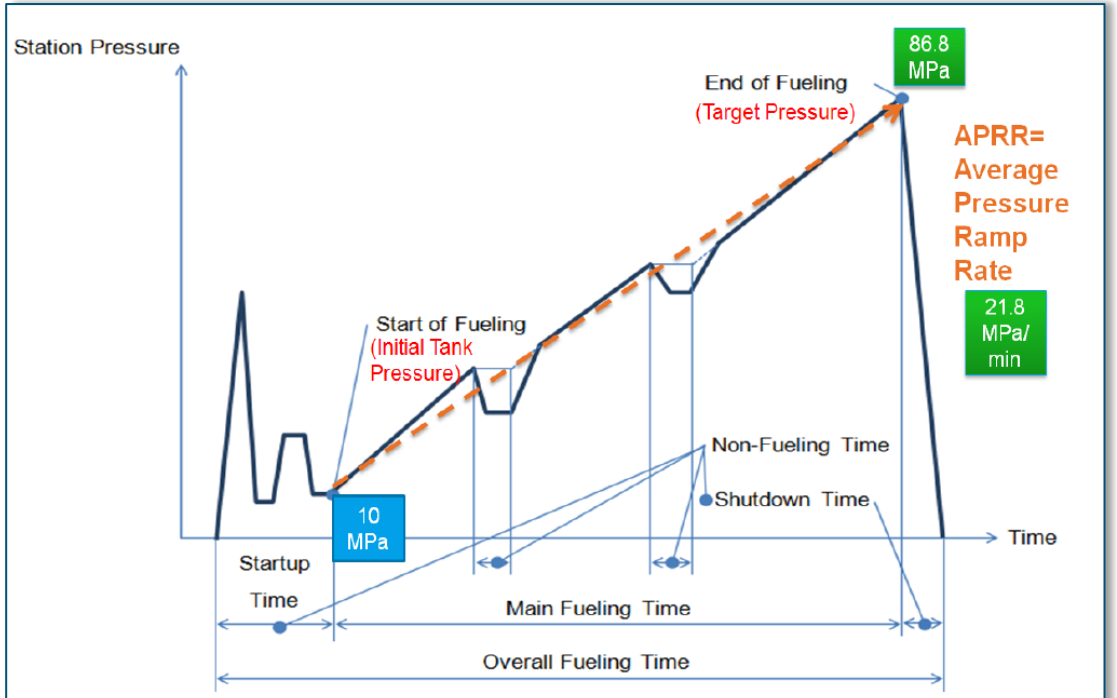
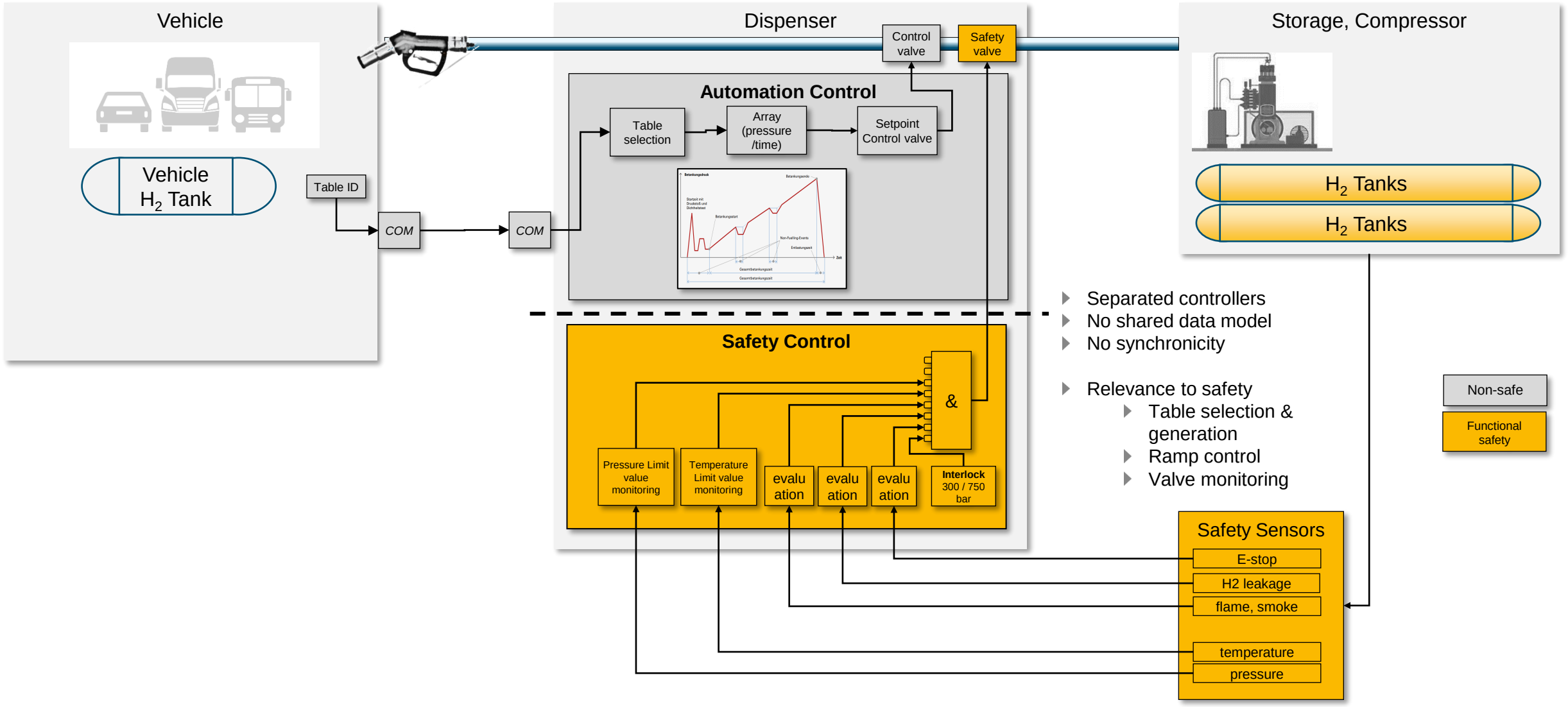


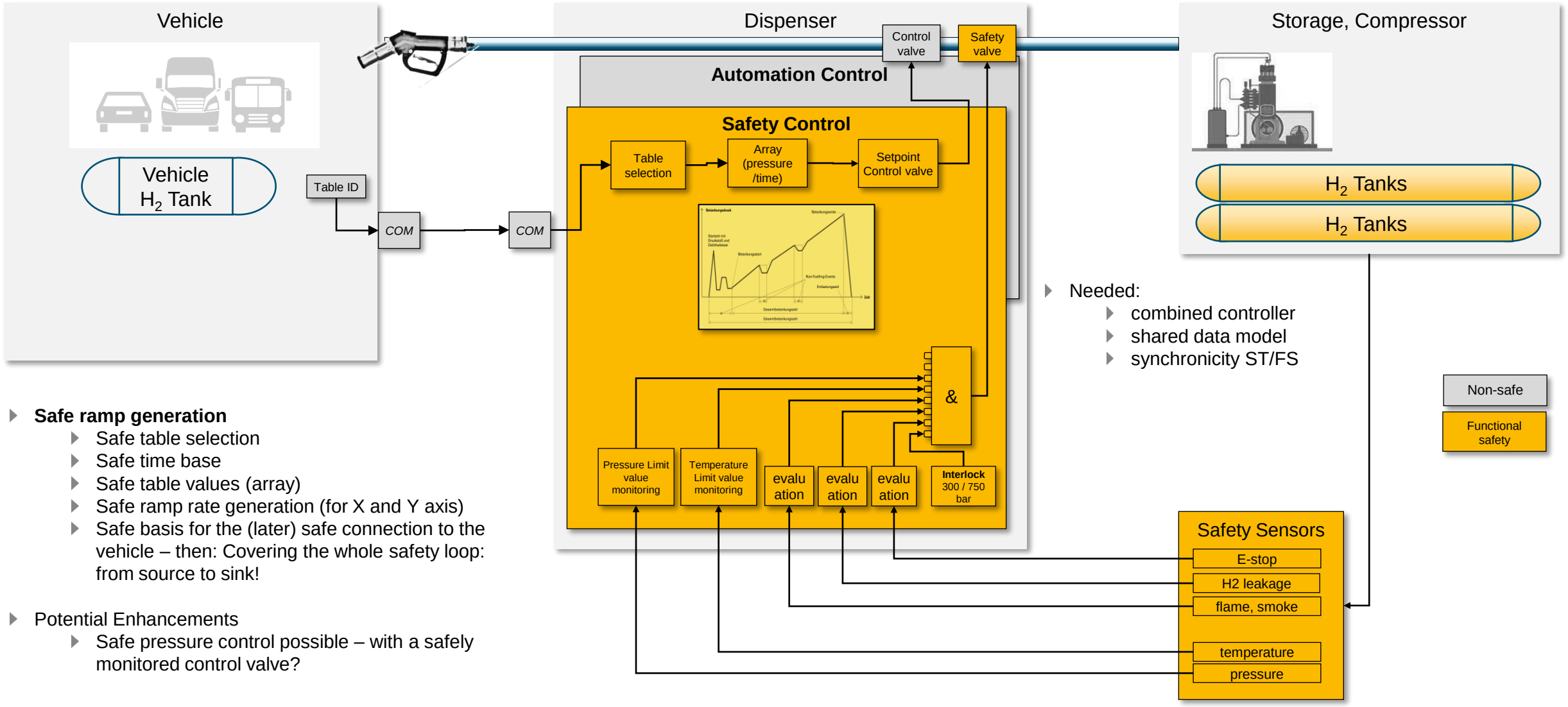
Figure 5 - Fueling Pressure vs. Time
Average Pressure Ramp Rate

- FCEVs store hydrogen fuel onboard in a compressed hydrogen storage system (CHSS), made up of hydrogen containers, valves, tubes and thermally-activated pressure relief devices. During the filling process of the CHSS, there is **a temperature rise of the gas within the container(s)** (Type III or IV) due to heat of compression effects and other thermodynamic phenomenon.
- This heating effect is later dissipated over time through the container walls and fittings. The **fueling protocol must ensure that the hydrogen in the CHSS does not exceed its maximum operating temperature.**

Refuelling pressure control + safe monitoring (TODAY)

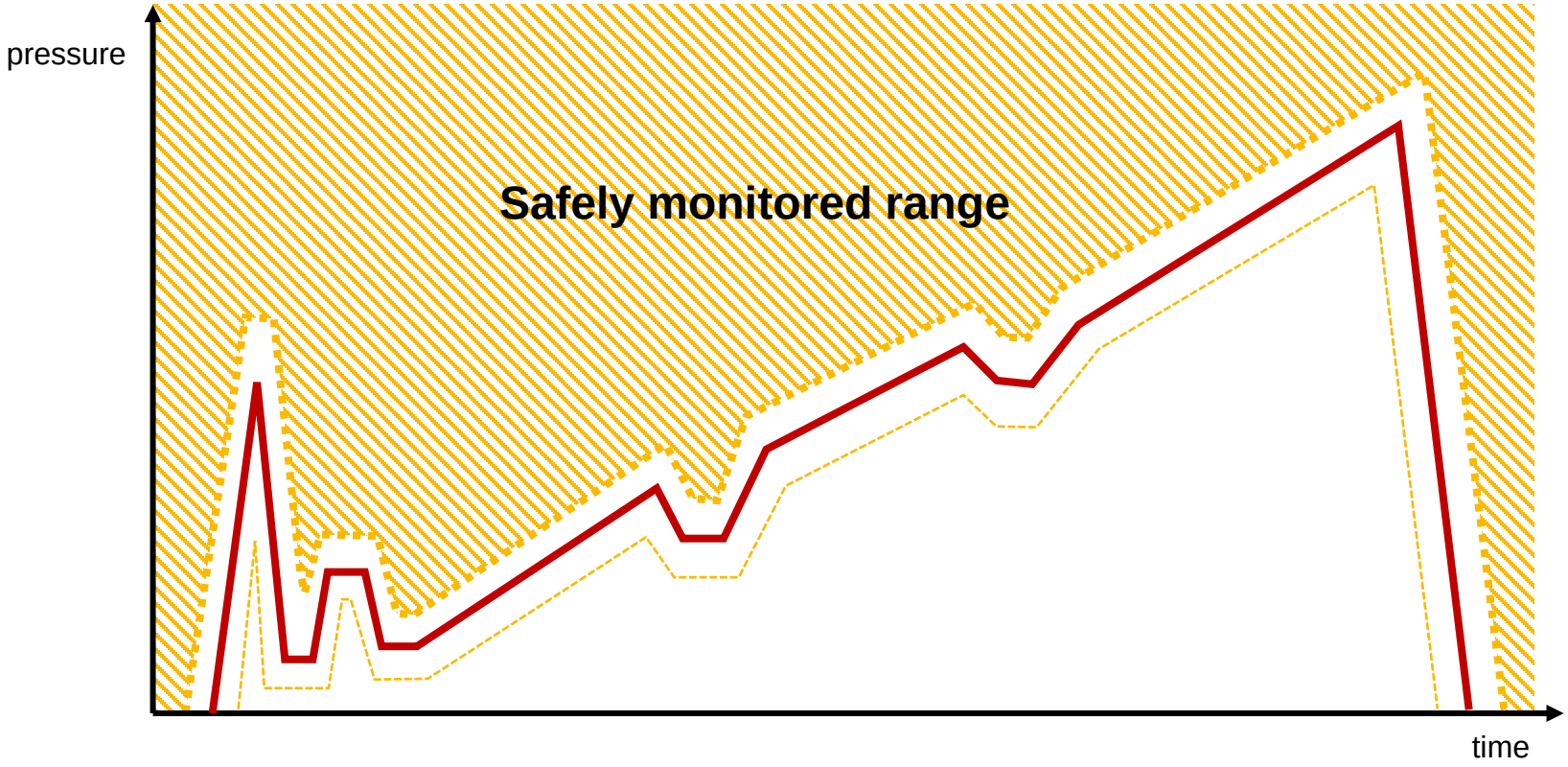


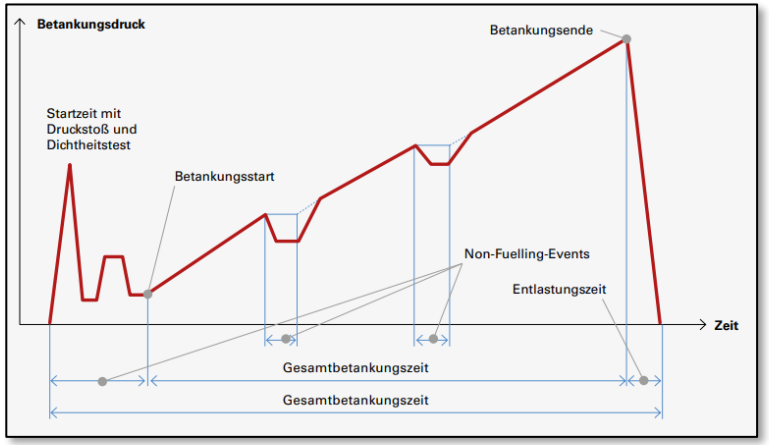
Refuelling pressure control + safe monitoring (TOMORROW)

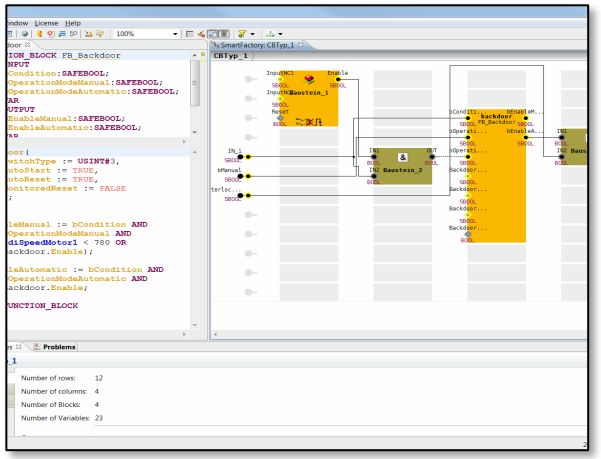


- **Safe ramp generation**
  - Safe table selection
  - Safe time base
  - Safe table values (array)
  - Safe ramp rate generation (for X and Y axis)
  - Safe basis for the (later) safe connection to the vehicle – then: Covering the whole safety loop: from source to sink!
- Potential Enhancements
  - Safe pressure control possible – with a safely monitored control valve?

Refueling pressure + safe monitoring







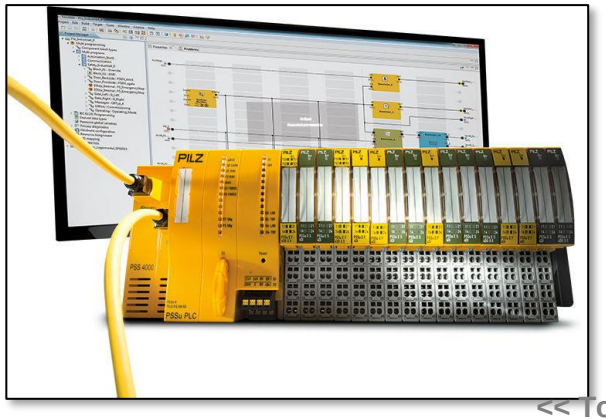
Safety
Automation

Standard
Automation

Completely free mixable with exactly the same functions

- Setpoint for the pressure control valve (non-safety; ST)
- monitoring of dynamic limit values (safety, FS)

- Need for a synchronous control operation of ST and dynamic FS
- fixed safe pressure monitoring limits cannot solve this
- But:
  - combined ST/FS PLC
  - with safe arrays, safe counters, safe timers, safe PID control, safe calculation…



Safety & Automation Control

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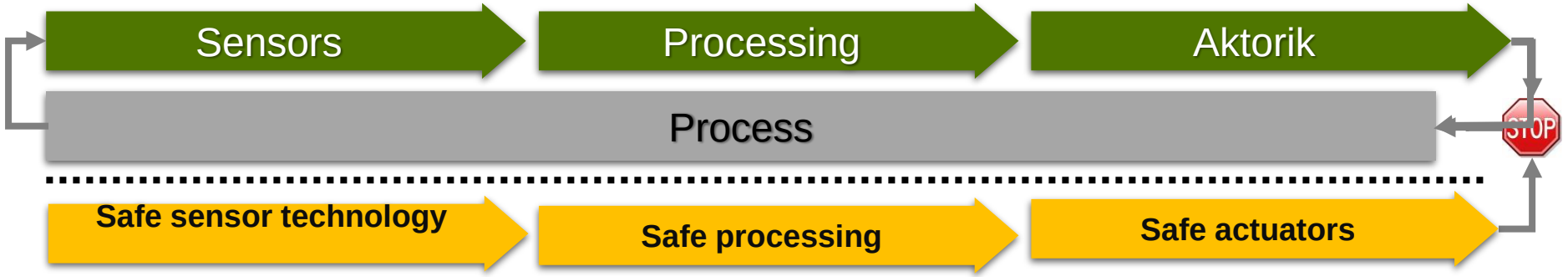
Technology in transition: functional integration of safety and automation



- Separating protective device
- Binary switching behavior

- direct coupling (wiring logic)
- Direct direction of action – direct reaction

- Rigid coupling (wiring logic)
- Direct direction of action – direct reaction
- direct coupling (wiring logic)
- Direct direction of action – direct reaction

Safety switch

Safety relay

Contactor (Bildquelle Eaton)

Hydr. Press safety valve (Bildquelle Norgren)

Pneumat. Safety valve (Bildquelle Festo)

Technology in transition: Fusion of safety and automation

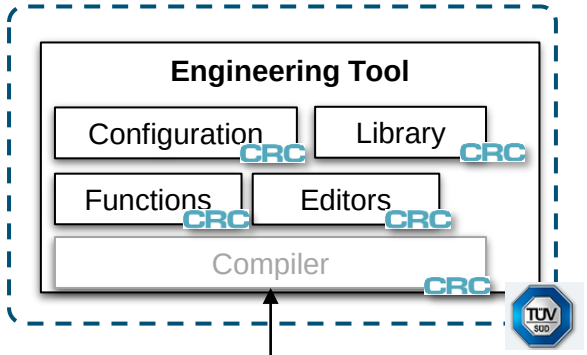
- safe detection of position and speed
- Differentiation into warning and shutdown areas
- Multi-dimensional monitoring
- dynamic protection areas
- ….

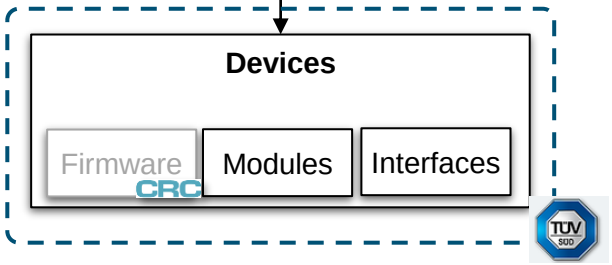
- Safety & Control & Motion
- flexible coupling (functional logic)
- Operating modes (safe & functional)
- Identification (security & functional)
- Exchange of complex data
- Freedom from repercussions physically mixed – but logically separated

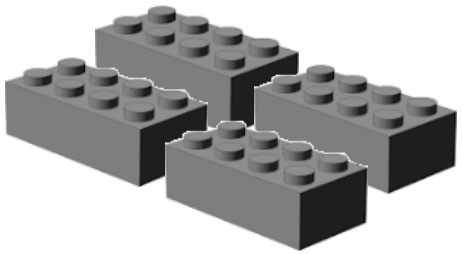
- Stop categories 1.2, safe stop, safe direction of rotation
- safe speed/safe standstill
- (safe) Position control
- (safe) Torque
- (safe) cooperating axes

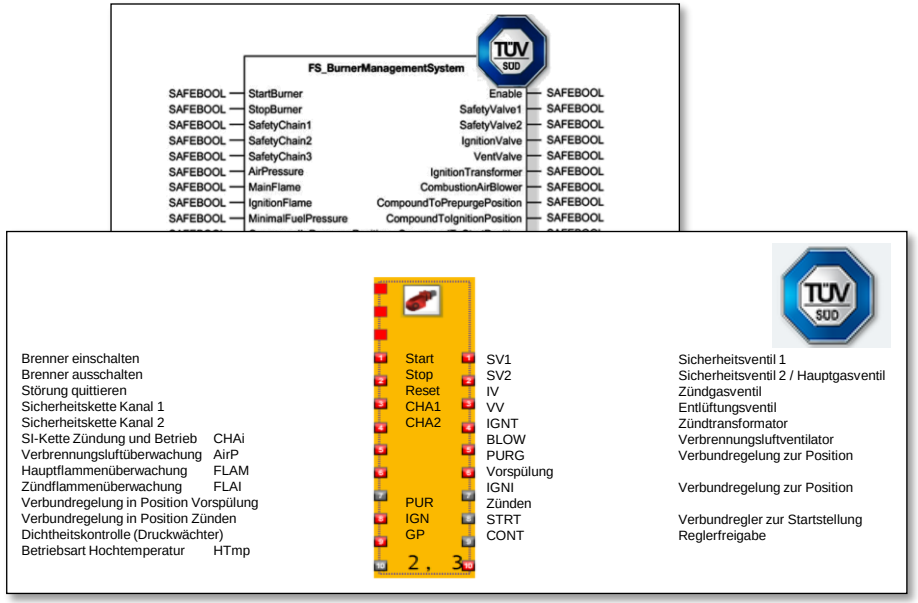
- Establishing safety through (safely) controlled process control
- Overall reliable process chain
- Shutdown only as an emergency measure = increase in productivity

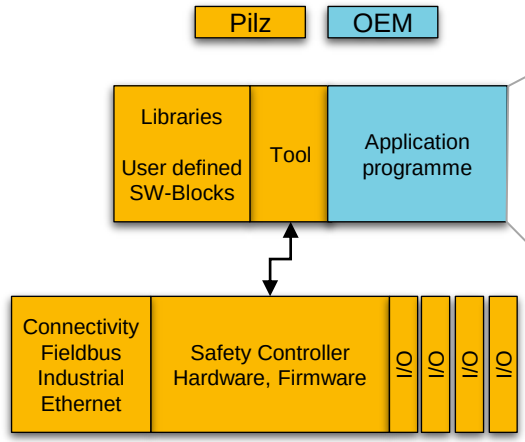
Encapsulation – for clearness of responsibilities

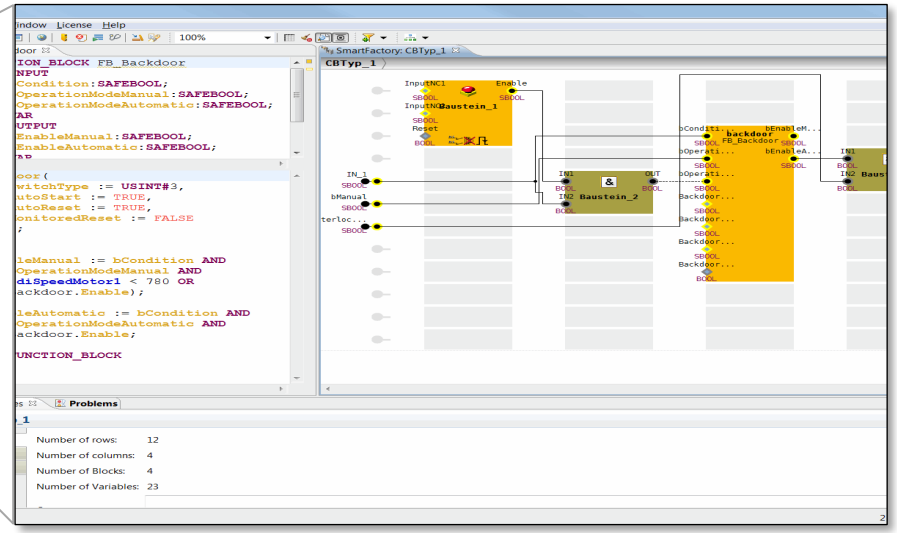












- All elements are sealed (safety certificate, responsibility, know how..)
  - Blocks
  - Configuration
  - User program
- All elements are protected by a system generated checksum CRC CRC
- Also sub-structures possible
- Allows a easy identification if and where changes have been made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FUTURE.
Wir
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