





Prac// toraten
platform voor praktische innovatie

H2CoVE

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Safety aspect of Hydrogen as an energy Carrier
Activities and Research of the Hydrogen in Industry Practoraat

Willem Hazenberg EUR ING MBA RI

Practor Hydrogen in Industry and Networks

03-12-2024 Groningen

daag jezelf uit

Co-funded by the European Union





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- **Practor Hydrogen in Industry and networks at Drenthe College**
- **Senior Consultant Bilfinger Asset Management Global Subject Matter Expert (SME) Hydrogen**
- Chairman of the HYDROGREENN Network
- Steering Committee Member NEN NP-H2-IGO
- Guest Lecturer – Hydrogen Safety at HanzePro
- Steering Committee Member WCM Hydrogen Maintenance
- Coordinator NL Drenthe College in Erasmus EU: Education in Hydrogen Technology Area and GreenSkills4H2
- Advisor for Green Deal Hydrogen Neighborhoods – Ministries of Economi Affairs and Climate (EZK), Interior and Kingdom Relations (BZK), and Infrastructure and Water Management (IenW)
- Liaison for GroenvermogenNL Human Capital Northern Netherlands, Mem of the Core Team for the R&D-HCA Agenda.
- Liaison Education Board Knowledge Center for Explosion and Hydrogen Safety
- Liaison GroenvermogenNL Noord Nederland team
- Liaison for GroenvermogenNL Northern Netherlands Team
- Project Manager / Practor Train and Learn Hub – Hydrogen Works
- Project Manager / Practor LLO Catalyst & H2COVE
- Group Leader and Board Member of KIVI Energy Transition Advisory Group

Film Hydrogen Practoraat in the Industry

- Film Hydrogen Practoraat in the Industry
- (894) Video Practoraat Waterstof Industrie – YouTube

- Practoraten.NL Research Focus and Publication
- Waterstof in de Industrie en Netwerken - Practoraten

- Green Hydrogen: what can Israel and the Netherlands achieve together?
- Green Hydrogen: what can Israel and the Netherlands achieve together?



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Hydrogen safety is an extremely broad topic



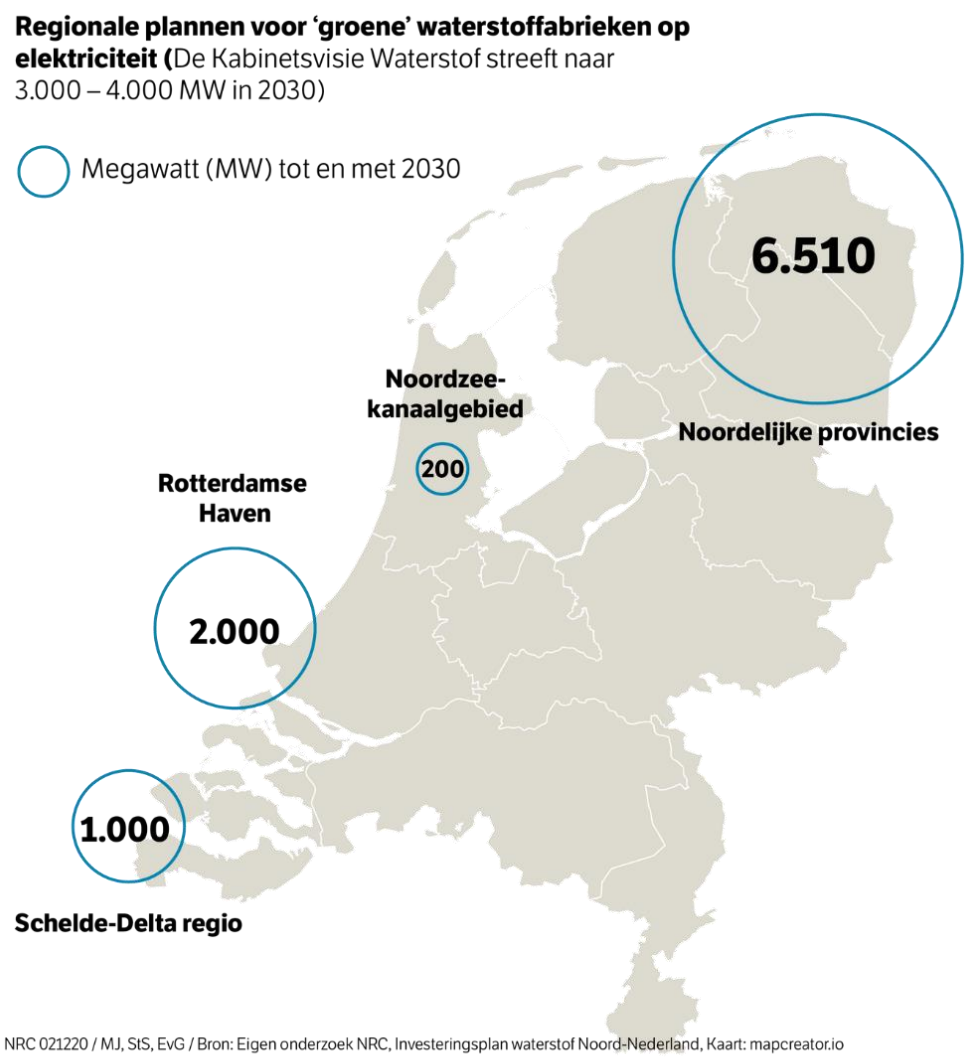
Don't compete on safety. Collaborate and share!

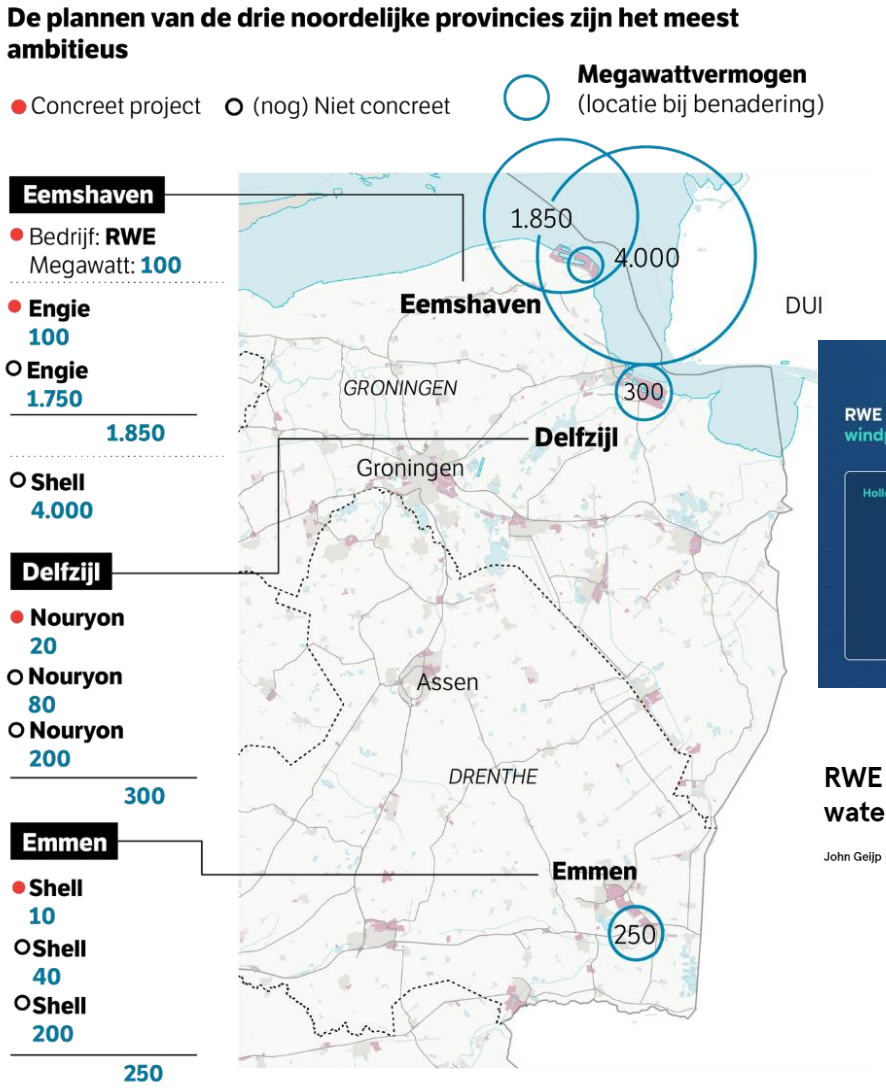
The research areas within the **Practorate Hydrogen in Industry and Networks**

- The **practoraat** will investigate the function and applicability of hydrogen (H2) in the industry. The focus will be on the production, transport, storage, applications, and maintenance of H2 as an energy carrier and raw material.
- Developing the elective course *Hydrogen and Industry* for teachers and students.
- Hydrogen safety.
- Designing a hydrogen asset breakdown to establish failure behavior, inspection, and maintenance structures.

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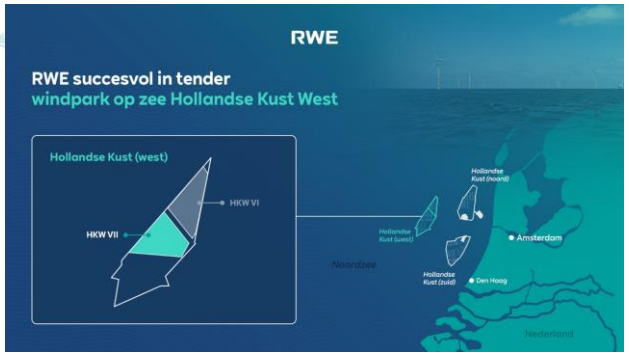
Regional hydrogen plans in the Netherlands





50 MW start
Scaling up to 600 MW by 2027 (RWE)

[Persbericht RWE 10-11-22]

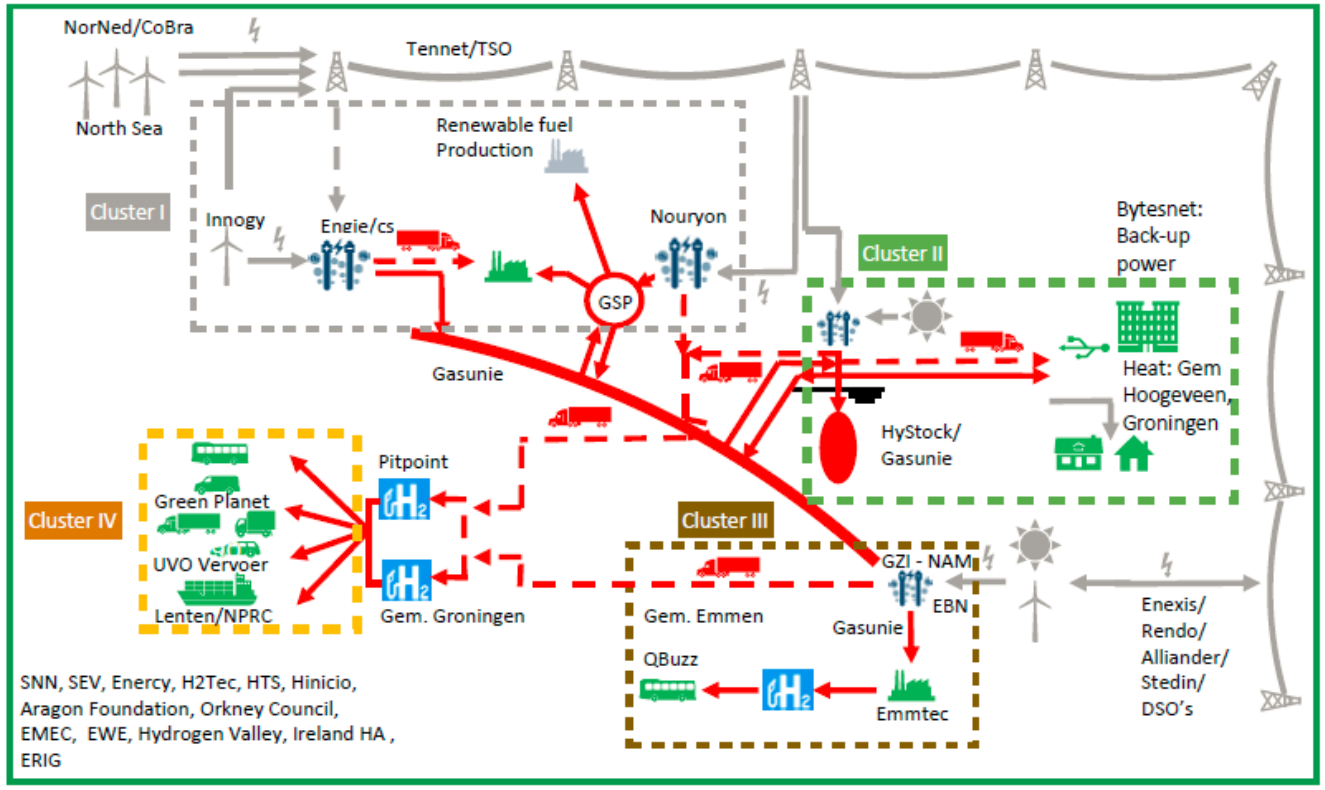


RWE gaat met elektriciteit nieuw windpark waterstof maken in Eemshaven

John Geijp · 11 november 2022, 18:56 · Economie

Deel dit artikel

EU HEAVENN project



Hydrogen Energy Applications for Valley Environments in Northern Netherlands

The Movie:

https://vimeo.com/368013901



provincie groningen

Home · Actueel · Nieuws

Europese miljoenen voor ontwikkeling waterstoftechnologie in Noord-Nederland

30 augustus 2019

Noord-Nederland is door Europa aanwezen als de regio waar de komende jaren de groene waterstoftechnologie zich verder moet ontwikkelen. Vanuit Brussel gaat er € 20 miljoen subsidie naar het project Hydrogen Valley, gericht op de ontwikkeling van een volledig functionerende groene waterstofketen. Het project kost in totaal € 90 miljoen, duurt zes jaar en gaat begin 2020 van start.

Internationale steun

De subsidieaanvraag is ingediend door HEAVENN, een samenwerkingsverband van 31 publieke en private partijen uit zes Europese landen. De leidende partijen bij de aanvraag waren het Samenwerkingsverband Noord-Nederland (SNN) en de New Energy Coalition. Bij het traject werden de partijen internationaal ondersteund, onder meer vanuit de Verenigde Staten en Japan. Het HEAVENN-project is bijzonder, omdat het de hele waterstofketen omvat en verbindt binnen één geografische regio.

Noord-NL as the premier hydrogen region of the Netherlands and Europe

- Greening the existing gas-based economy
- NAM sites & pipelines available in the near term
- Significant sustainable energy developments (both on land & at sea)

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Employment through hydrogen

- "(The switch to hydrogen as an energy source could create up to 41,000 new jobs in the Netherlands)" (Van de Sander 2021)
- (European commission JRC technical report, Spisto, et al. 2020, 13)
  - States that the planned 100 MW hydrogen projects through 2030 in Groningen and Drenthe will create 6,000 FTEs of employment during the construction phase and 500 FTEs during operation.

year CE Delft study 2021	Demand for green hydrogen PJ	Total one-time employment (average FTE/year)	Recurring employment (average FTE/year)
2030	10 – 40	1.800 - 4.700	4.200 - 12.500
2040	132 – 317	2.000 - 13.000	9.200 - 43.000
2050	254 - 593	2.200 - 20.000	14.200 - 72.600

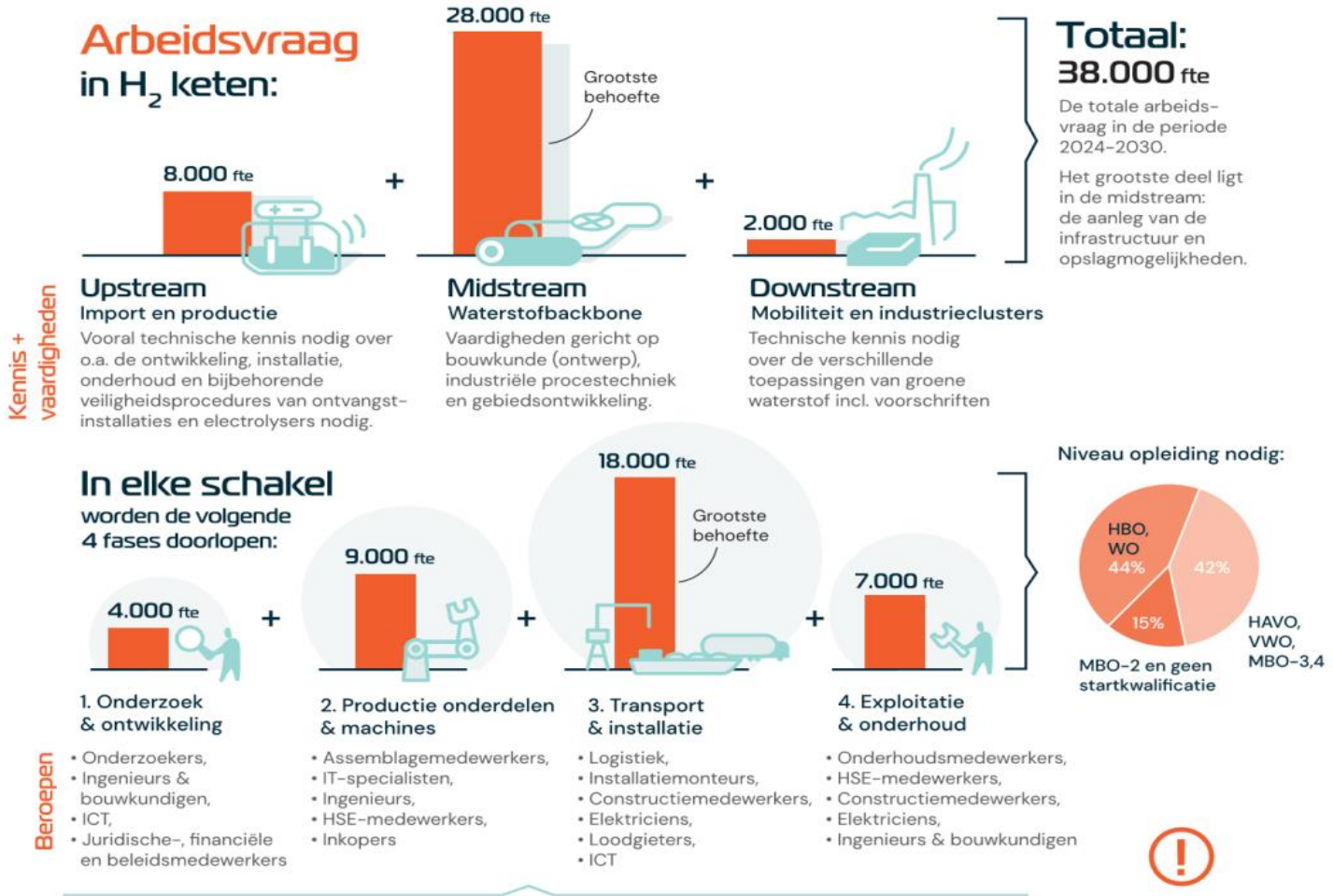
Source of the table and chart: CE Delft, April 2021: Overview of labor demand (rounded to the nearest hundred)

- Hydrogen is one of the few areas where employment opportunities exist throughout all parts of the value chain.
- Therefore, it is especially important to preserve jobs that may be lost and to reuse that expertise, potentially with additional training.

https://publications.jrc.ec.europa.eu/repository/bitstream/JRC120521/socio-economic_impacts_closure_groningen_gas_field.pd
CE_Delft_200427_Werk_door_groene_waterstof_investeringen_DEF.pdf

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Hydrogen transition labor market



Bron Groenvermogen/CE Delft 230143 - Arbeidsmarktonderzoek waterstoftransitie – September 2023 Infographic

WO/HBO	**= 44%**
HAVO/VWO/MBO-3/4	**= 42%**
MBO 2 en lager	**= 15%**

[CE_Delft_230143_Arbeidsmarktonderzoek_waterstoftransitie_Def.pdf]

Challenges in Filling Crucial Roles for the Energy Transition

Challenges in Filling Crucial Roles for the Energy Transition:

High International Demand for Technical Personnel

Professionals with a technical background are particularly sought after.

Low Enrollment in Education Due to Demographic Effects

This is especially a problem in the Netherlands.

Budget Cuts in Education Cause Additional Financial Pressure

Technical programs are more expensive and more likely to be discontinued.

Limited Mobility of Vocational (MBO) Students

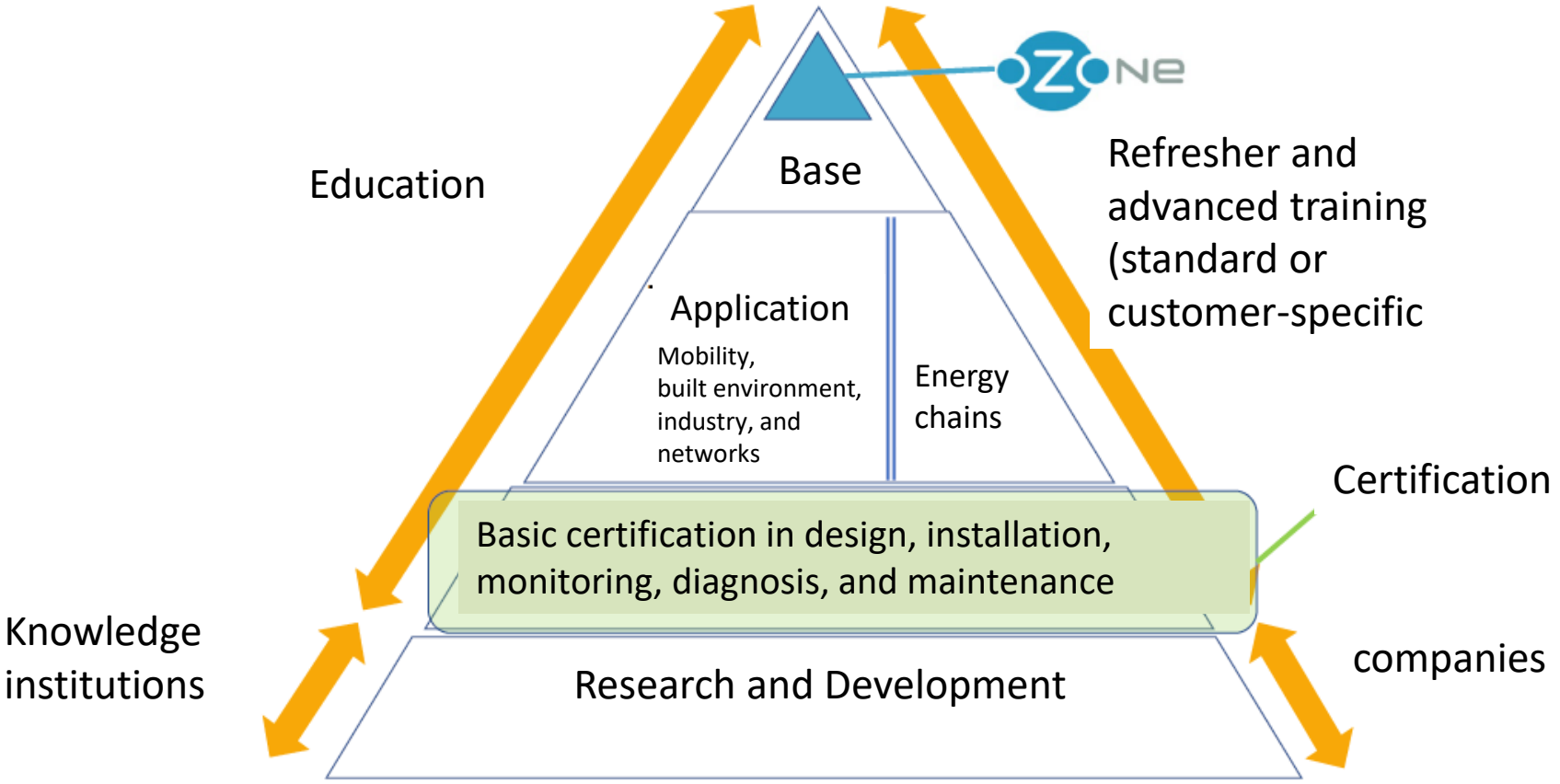
Students are unwilling to travel far for technical education, leading to decreased enrollment when training locations change.

Demand for Broader Technical Skills

Beyond mechanical engineering, knowledge in process engineering, electrical engineering, instrumentation, and basic automation is now required.

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Basic model for hydrogen education

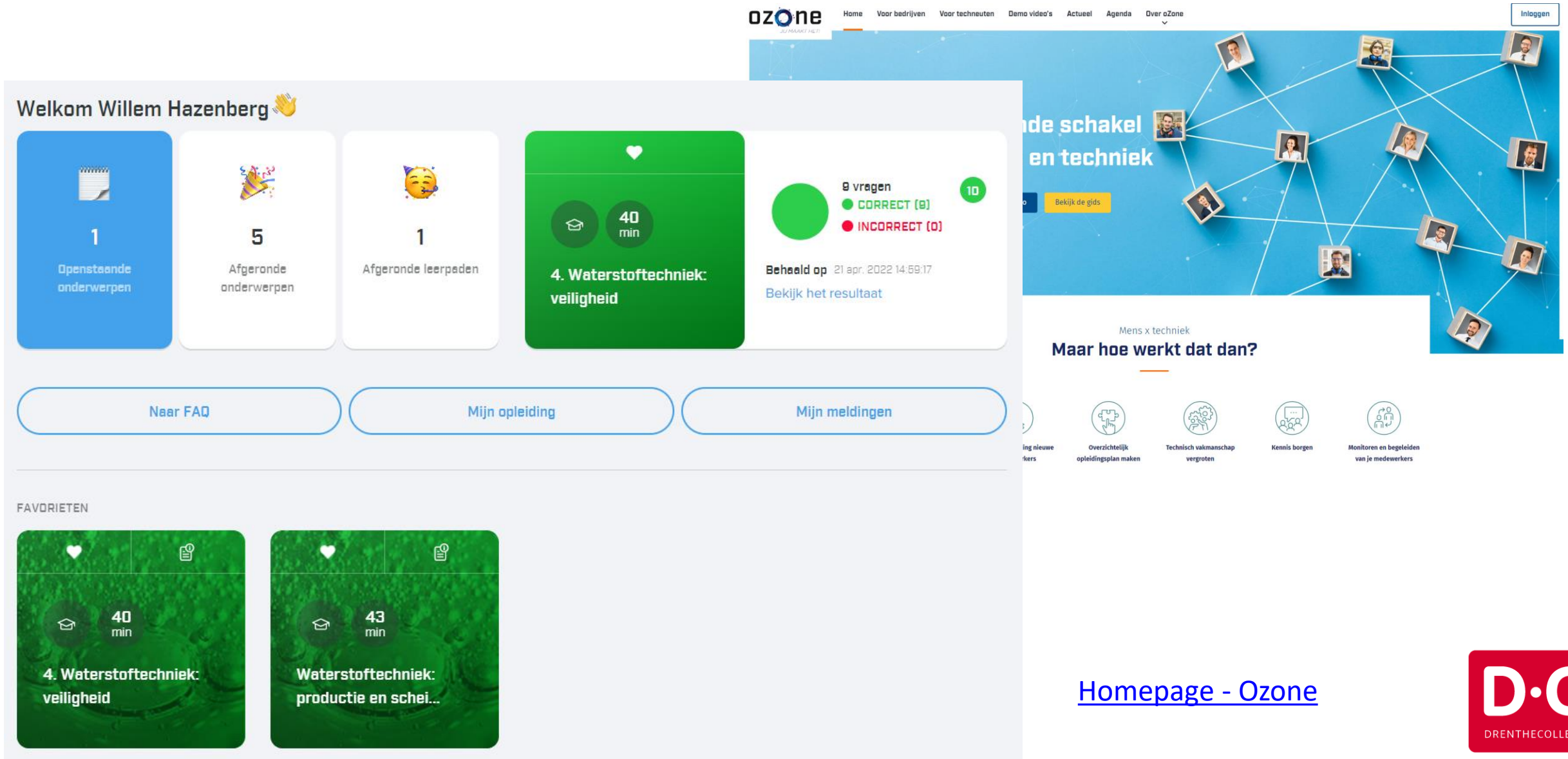


Afbeelding Roeland Hogt Noorderpoort

Hydrogen training options in both public and private education, as well as from commercial providers

New Energy Business school Post HBO waterstof specialist 29 dagen – 8 maanden programma 	Post HBO	Video Link	12.500 euro
oriëntatie cursus waterstof Technologie KC1049 7 weken (SBU 240)	MBO 3/4	Link	1.395 euro
TU Delft MOOC Sustainable Hydrogen and Electrical Energy Storage SBU 112	HBO/WO	Link	Gratis
E-Learning OZONE.NL – (10 les modules energy College 7 gereed)	MBO 3		
Inleiding in het analyseren en reduceren van veiligheidsrisico's bij het ontwerpen van waterstofinstallaties HANZEPRO WATERSTOF HAN TVVL **Waterstof in de gebouwde omgeving**	MBO/ HBO		Circa 1.500-2.500 euro
3-5 daagse opleiding – verbreding en verdieping in een onderdeel			
1 daagse opleiding – Basiscursus soms masterclass genoemd	MBO/ HBO		Circa 400-600 euro

E-Learning - Ozone.nl



[Homepage - Ozone]

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Ozone - Dutch

• Hydrogen fundamentals	(32 min)	Energy College
• Hydrogen technology: safety	(40 min)	Energy College
• Hydrogen technology: production and chemistry	(43 min)	Energy College
• Hydrogen technology: storage and transport	(28 min)	Energy College
• Hydrogen technology automotive	(31 min)	Energy College
• Hydrogen technology fuel cells	(42 min)	Energy College
• Hydrogen technology maritime	(28 min)	Energy College
• Energy storage(incl. H2)	(36 min)	Project 0ne

Homepage - Ozone

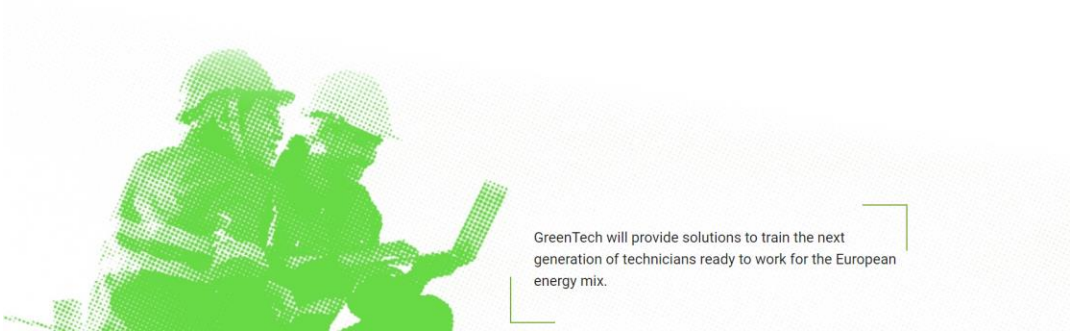
MOOC Greentech
Europe trains technicians in renewable energies





[Teaser for the MOOC (youtube.com)]

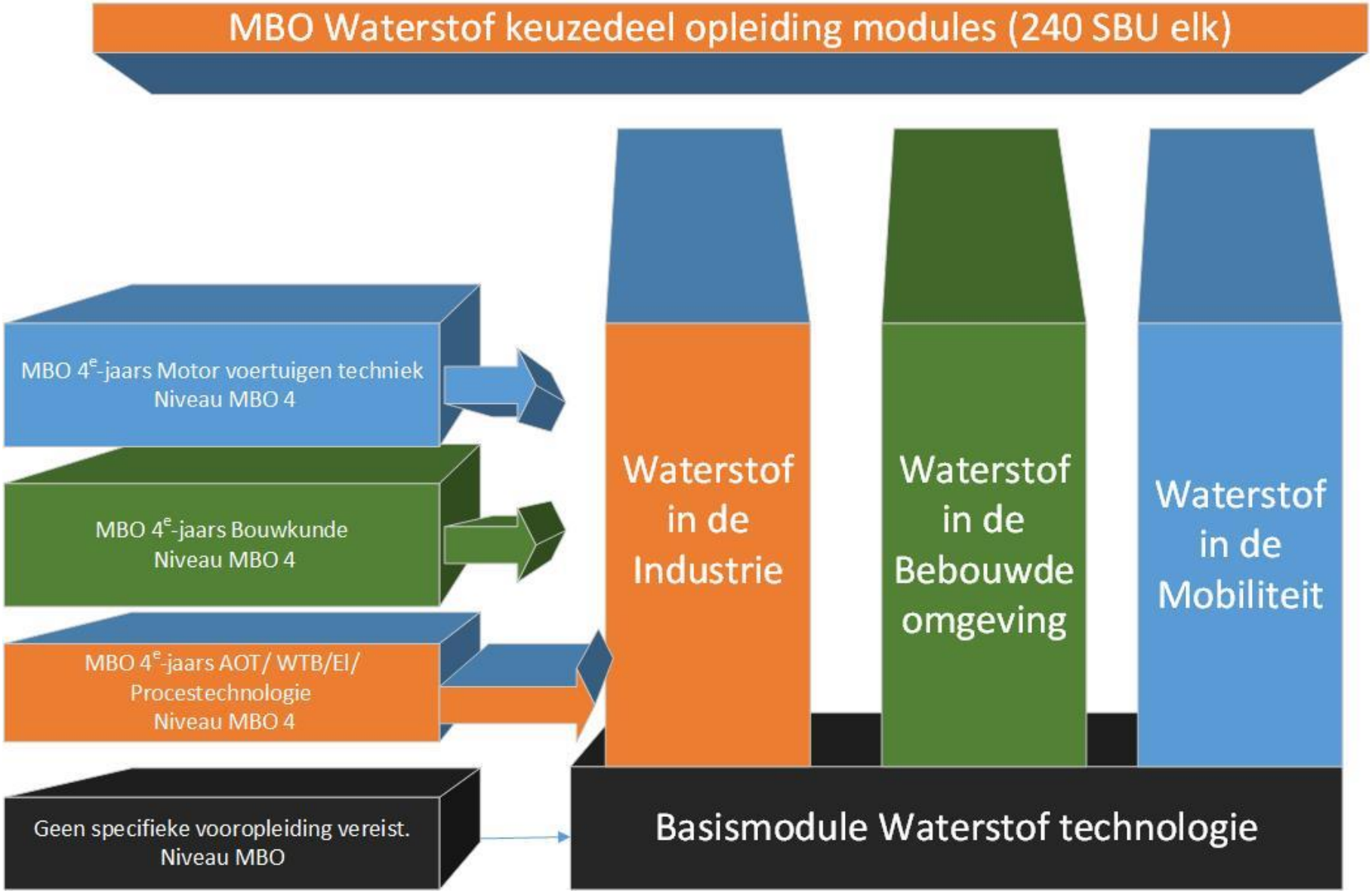
https://youtu.be/VnwJGPhwIKk



Training modules
Introduction
Training module 1: Solar energy
Training module 2 : Wind energy
Training module 3: Network management and storage
Training module 4 : Green hydrogen production
Training module 5: Usages

- Renewable Energies Technician Program - GREENTECH Erasmus (greentech-erasmus.eu)

Hydrogen elective modules (240 study hours each)



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Hydrogen elective modules (240 study hours each) SBB links

SBB Waterstoftechnologie
MijnSBB - Portal Kwalificatiestructuur

SBB Industrie en netwerken
MijnSBB - Portal Kwalificatiestructuur

SBB bebouwde omgeving
MijnSBB - Portal Kwalificatiestructuur

SBB Waterstof mobiliteit
MijnSBB - Portal Kwalificatiestructuur

beroepsonderwijs bedrijfsleven

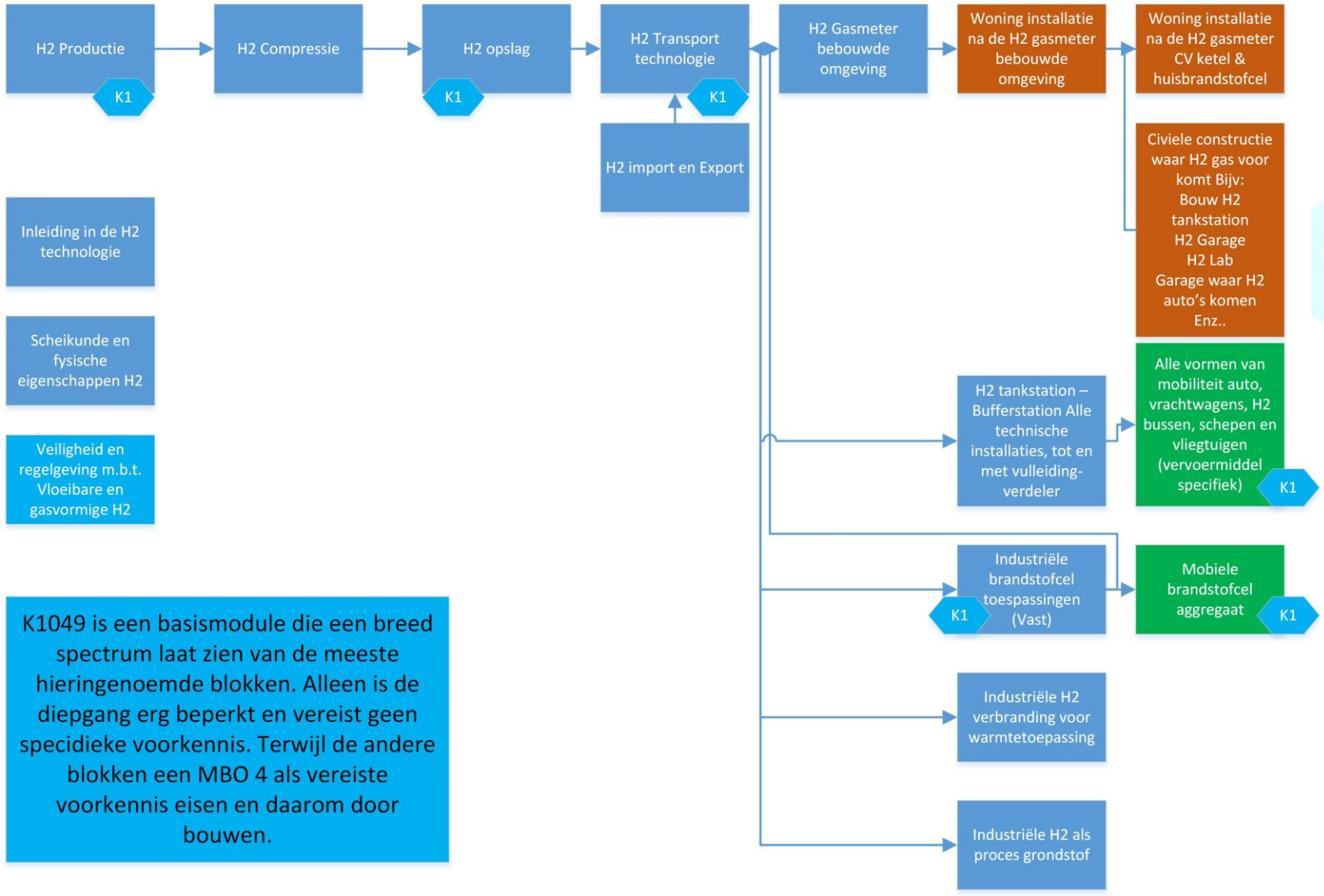
Keuzedeel mbo

Waterstof in de industrie

Naam keuzedeel	Code	Aantal sbu	Nieuw of bestaand	Vorige versie	Toelichting
Waterstoftechnologie in de gebouwde omgeving	K1318	240	Nieuw		
Waterstof in de industrie	K1319	240	Nieuw		
Waterzijdig inregelen van verwarmingsinstallaties	K1320	240	Nieuw		

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Waterstof Logistieke keten en verdeling opleidingen (WHB 9-11-2021)



Sectorkamer SBB

beroepsonderwijs bedrijfsleven

Keuzedeel mbo

Waterstof in de industrie

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Future job roles of MBO (VET) students

1. Operating these installations.
2. Ensuring that others can work safely at a hydrogen installation.
3. Roles during the construction of these installations.
4. Carrying out inspection tasks.
5. Performing maintenance.
6. Broader knowledge required across multiple disciplines due to decentralized systems.

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Required knowledge for future job roles of MBO/VET students

- What is a hydrogen installation, what components does it contain, and how does it operate?
- What maintenance is required, where, how, and how often?
- What needs to be inspected, where do the risks lie, and why?
- Which work procedures should be used when performing maintenance? What safety measures must be taken into account?

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Hydrogen in Industry Competencies

- **Knowledge**
  K01: Application areas of hydrogen technology in industry
  K02: Advantages and disadvantages of hydrogen technology for industry
  K03: Operation and characteristics of the relevant (sub)systems in industrial hydrogen technology
  K04: General safety aspects and regulations for liquid and gaseous hydrogen
  K05: Specific safety aspects for hydrogen in industry
  K06: Design requirements specific to the industrial sector
  K07: Materials and components used in hydrogen technology in an industrial environment
- **Skills**
  V01: Implement necessary safety measures when working with hydrogen technology in an industrial environment
  V02: Collaborate and communicate with technicians from multiple disciplines
  V03: Install and operate technical (demonstration) systems involving hydrogen technology in an industrial setting
  V04: Interpret technical drawings in hydrogen technology and the associated process flows
  V05: Operate relevant modern technical equipment
- **Work Processes**
  D1-K1-W1: Prepare installation activities
  D1-K1-W2: Place and assemble components and parts
  D1-K2-W1: Locate and analyze problems
  D1-K2-W2: Adjust and fine-tune equipment and installations, and resolve issues

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MBO Hydrogen - Industry elective module time distribution (240 total)

Hydrogen for Industry and networks
8 hours Final Test for Practice
4 hours Final Test for Theory incl. presentation case study
100 hours Final Assignment
8 hours Site Visit, for example, GETEC and Resato
8 hours EnTranCe Electrolysis
8 hours Virtual Reality Environment
10 hours Ozone Online / EHTA Modules
24 hours Practical Lab for DC and DC Fuel Cell
20 hours Answering Homework Questions
48 hours Theory Lessons in 24 Blocks of 2 Hours

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• Program Hydrogen in in Industry and Network 1/2

Program 24 lessons of 2 hours

- introduction 3 lessons
- Safety 3 lessons
- Downstream 6 lessons
- midstream 6 lessons
- Upstream 4 lessons
- Material - couplings 1 lesson
- Business and case notes 1 lesson

KD (professional knowledge and skills)	class week	lesson hour Block of 2 hours	Main group	Description
basic	1	1	introduction	Introduction to hydrogen technology course
basic/D1-K1-2c	2	2	introduction	Background energy transition Climate Agreement/EU Fit for 55, CES and Pros and Cons H_2 , Resource use, rare earths, Water, space occupation,
basic	3	3	introduction	Hydrogen Basic concepts Physical & Chemical properties, Gas quality Conversion methods
D1-K1-1a	4	4	Safety	Permits and regulations environmental permit, QRA study, BZRO, Hydrogen calamity abatement
D1-K1-1b/c /1e - D1-K1-5a/D1-K1-2c	5	5	Safety	Hydrogen ATEX and Ventilation - PED, Maintenance plan and causes of failure, Hydrogen materials and Embrittlement (Friability)
D1-K1-1b/1C/1f	6	6	Safety	Hydrogen safety Site and Installation safety, /ESD/SIS and Hydrogen PPE guidelines for site , Risk inventory HAZOP

The Hydrogen in Industry course will begin for the first time with a group of students at Drenthe College - Greenwise Campus in September 2023.

• Program Hydrogen in Industry and Network 2/2

D1-K1-2b	7	1	Downstream	Hydrogen Technology, Production 1, incl. Colors hydrogen green, blue, gray.+ CCS technology - Project Porthos plus simulation models show
D1-K1-2b	8	2	Downstream	Hydrogen Technology, electrolysis
	9	3	Downstream	Utilities (Nitrogen and air), Water treatment
D1-K1-2b	10	4	Downstream	Hydrogen Technology, Power Supply, Hydrogen Technology, Measuring Equipment and Sensors
D1-K1-6b/6c	11	5	Downstream	Hydrogen Technology, PLC/ESD/SIS/ Process control
	12	6	Downstream	Excursion to hydrogen downstream facility or Lab assignment

KD (professional knowledge and skills)	class week	lesson hour Block of 2 hours	Main group	Description
D1-K1-2b	13	1	Midstream	Hydrogen Technology, storage
	14	2	Midstream	Imports, TSO (HYway27) DSO, energy islands incl. economy
D1-K1-2b	15	3	Midstream	Hydrogen infrastructure TSO - DSO
	16	4	Midstream	Hydrogen blending , Hydrogen and heat grids
	17	5	Midstream	Hydrogen fueling stations
D1-K1-2b	18	6	Midstream	Hydrogen Technology, Compression
	19	1	Upstream	Hydrogen Boilers, Gas Turbines
	20	2	Upstream	Hydrogen in built environment, Hydrogen Energy Hubs
	21	3	Upstream	Hydrogen fuel cells
	22	4	Upstream	Hydrogen as a chemical feedstock NH3 LOHC DME Methanol
D1-K1-3a	23	5	Material - couplings	Hydrogen couplings - Welding - flange - Clamp couplings - Swagelok
D1-K1-2a	24	6	Business and case notes	Business Economics. Merit order - Budgeting - Basic engineering process and study cases for review

Vision on LLO modules

- The LLO modules must meet two key conditions:
- They offer students a broader foundation than the existing basic modules, enabling them to perform a task independently.
- Each module can be taken on its own, potentially combined with a limited number of existing elective components.
- **Additionally:**
- There should be minimal overlap between the different modules to prevent redundancy.
- The modules should be as small as possible, focusing on teaching one specific skill per module. This facilitates the creation of customized learning paths using various LLO modules.
- The aim is to structure the LLO modules so that the theoretical portion can be completed independently of time, location, and teacher availability.

This approach allows for flexible and efficient learning trajectories.

Opbouw LLO verdieping

VB LLO Specialisatie



In verdiepende modules wordt aan een onderwerp maximaal 2 lesuur besteed, dat geeft een mooi bredere basis maar is onvoldoende als je echt op dat onderwerp aan de slag wil.
Dan komen de LLO modules die dieper op 1 onderwerk ingaan. (Stel 5 EQF punten of 10 lesuren deels online).



3* Verdiepend keuzedeel

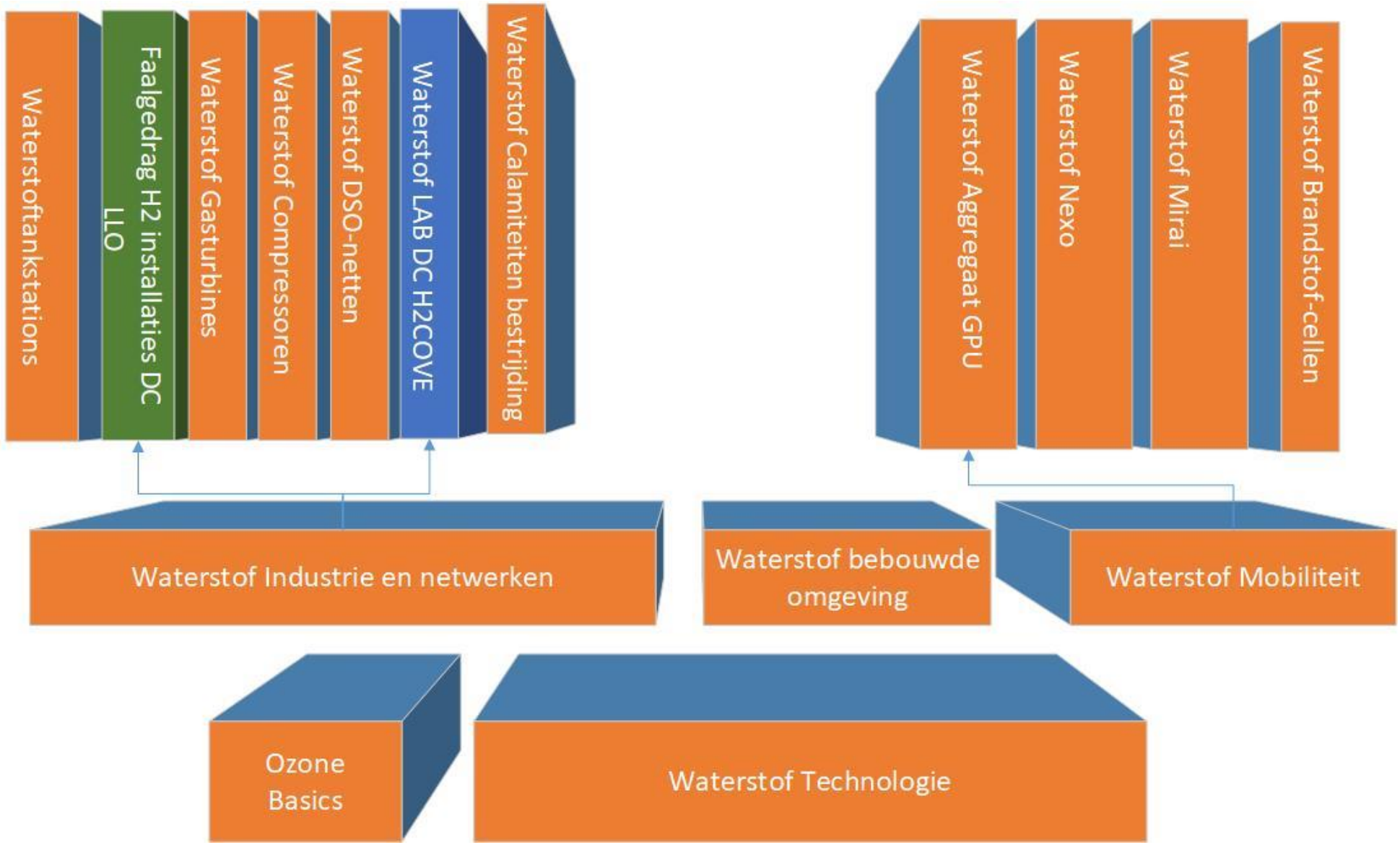


Basis kennis



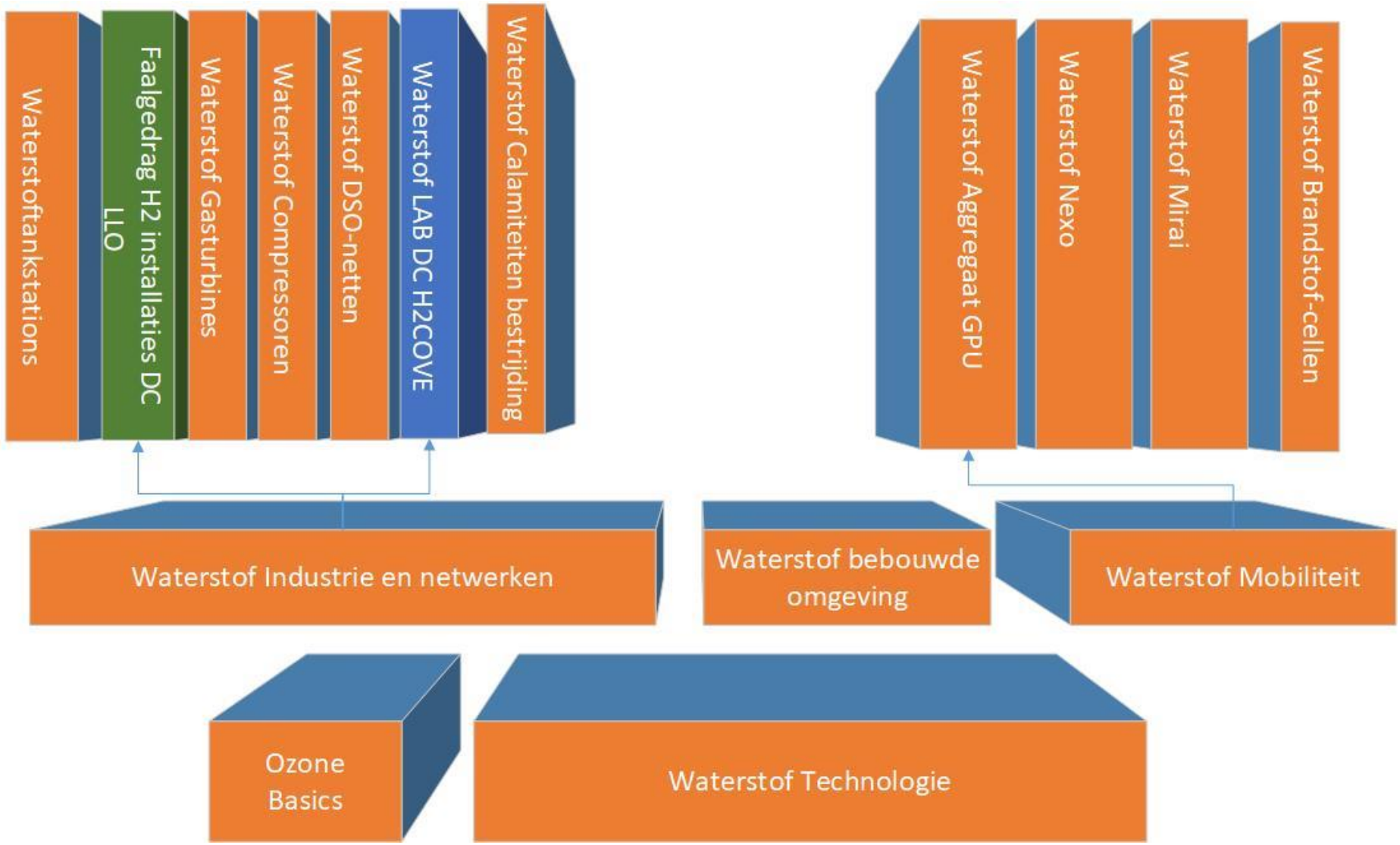
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Voorbeelden van LLO modules



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Examples of LLO (Lifelong Learning and Development) modules



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Hydrogen Assetmodel

Low	description	Department
Environment model	Climate, land features, Seismology	Engineers/licensing
Calamity model	Fire department ed. Emergency services	Government
Minimizing effects	Sprinklers - Tank Walls	WTB/Civil
PSV	Pressure Safety Valve	WTB
Security layer	ESD	IA
Control layer	PLC/DCS/ Sensors	IA
Communication layer	Networking - Cyber security	IT - A
Buffer layer		WTB
Production layer	Input transport low - output t/day	WTB/Process
Utilities	Flow - Air - Nitrogen - press pressure	WTB/Process
Emissions	Air water, Sound	Process
Heat balance		Process
Economic model		Business development/ finance/ procurement - sales
Maintenance and inspection model		EIA-WTB
HRM - Training - Soft skills		HRM

(PDF) NEBS Post HBO Waterstof Specialist Paper Willem Hazenberg v1.01_final en-US.pdf

Results - list of areas of work versus level of knowledge

Scope of work	Beginner	Advanced	Competent	Proficient	Expert
Engineering					
Production					
Installation					
Funding					
Operation					
Maintenance					
Safety					
Emergency Services					
Business and market introduction					
HRM - Training - Soft skills					
Environmental, Social and Governance (ESG) management and compliance					
Legal framework					

GreenSkills4H2 value Chain

FIGURE 26 - HYDROGEN VALUE CHAIN

Manufacturing			Project					Support	
Components & Material	Equipment	System Integrators	Developer	EPC	Production, Operation & Maintenance	Storage, Transport & Distribution	Usage	Public	Service Provider
Catalysts Membrane Valves Tubes Power electronics	Fuel cells Stacks Electrolyser Compressors Storage	Integrators of refuelling stations, power trains	Investors Project developer	Engineering Construction Commissioning	Production Operation Maintenance	Storage facilities, Transport infrastructure Trucking, Distribution network Refuelling stations	H2 off-taker Petrochemicals Refineries Fertilizers Mobility Oil & gas Power generation	Public agency Regions Support activities, or policy development, regulations, or certifications activities	Association H2 clusters Backbone Research institutions, IT providers Consulting



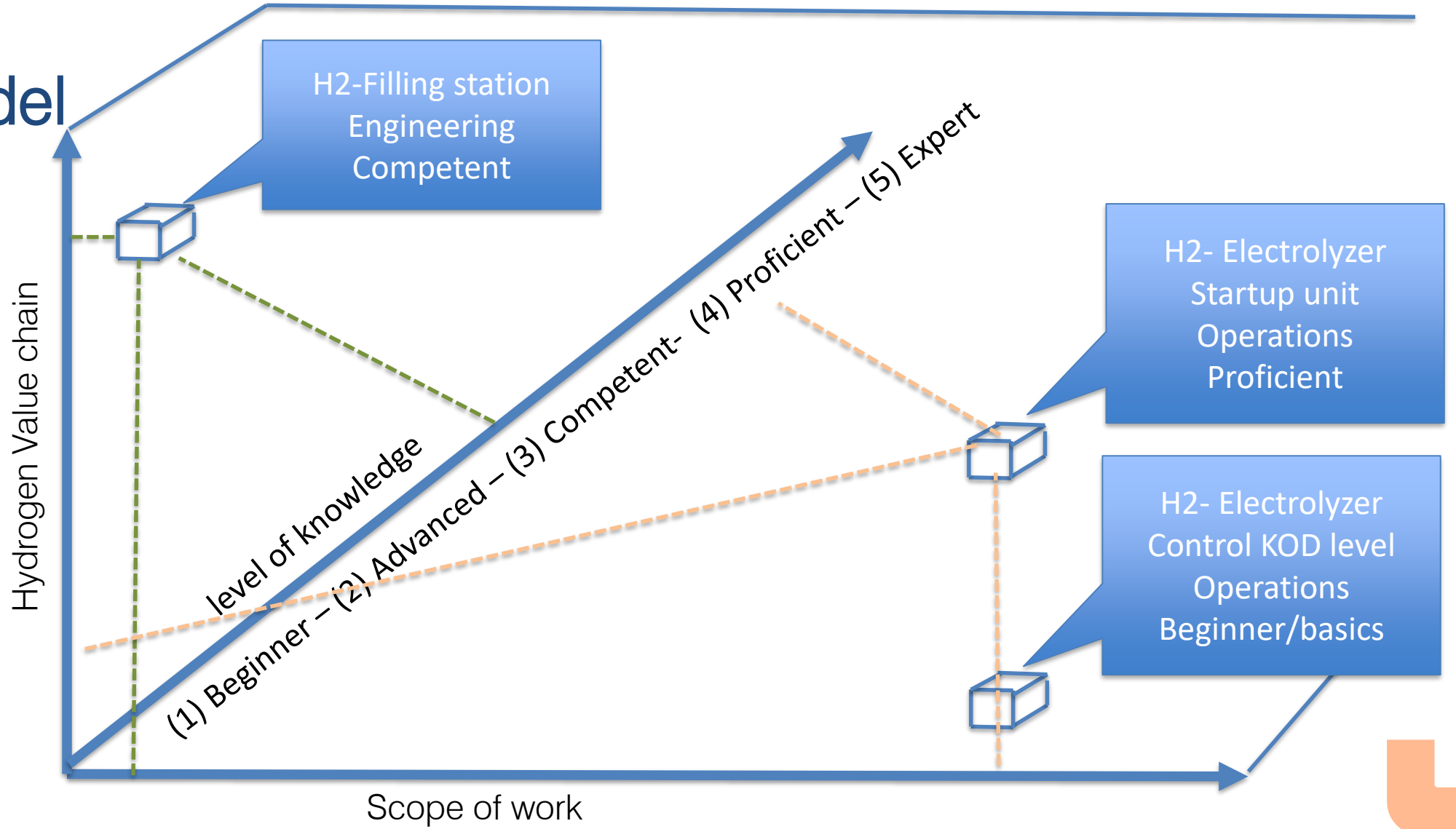
[Home - Green Skills for Hydrogen]

3D Model

Downstream
End use application

Midstream
Infrastructure

Upstream
Production H2



Engineering – production – Construction- Maintenance – operations – HRS - Legal

Which training products come from the practoraat

1. Hydrogen production methods
2. Hydrogen transport and infrastructure methods
3. Understanding the hydrogen economy and hydrogen chain integration
4. Hydrogen application in electrification
5. Hydrogen application in combustion
6. Hydrogen filling station applications
7. Hydrogen business economics
8. Hydrogen in the built environment (up to the gas meter, excluding civil works)
9. Hydrogen blending application (combustion)
10. Additional safety measures for working with H2
11. Regulations and enforcement related to hydrogen
12. Asset and maintenance strategies and procedures for H2
13. Knowledge alliance in Emmen and surrounding areas for hydrogen production, transport, storage, and usage
14. Process description for embedding acquired knowledge into the curriculum

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Course book Elective Module: Hydrogen in Industry and Networks



- The book is currently in development with a few key KPIs:
- Approximately > 1,300 pages
- 240 study hours
- 48 teaching hours
- The book is primarily designed for MBO education but is also suitable as a reference work for HBO and university-level (WO) education.

Hydrogen practical training at DC Emmen and EnTranCe







Through this set, students can acquire 30 hours of hydrogen-related knowledge at DC in Emmen

EnTranCe installation with 100 kg of H2 available, reduced from 200 bar to 8 bar, under VCA regulations

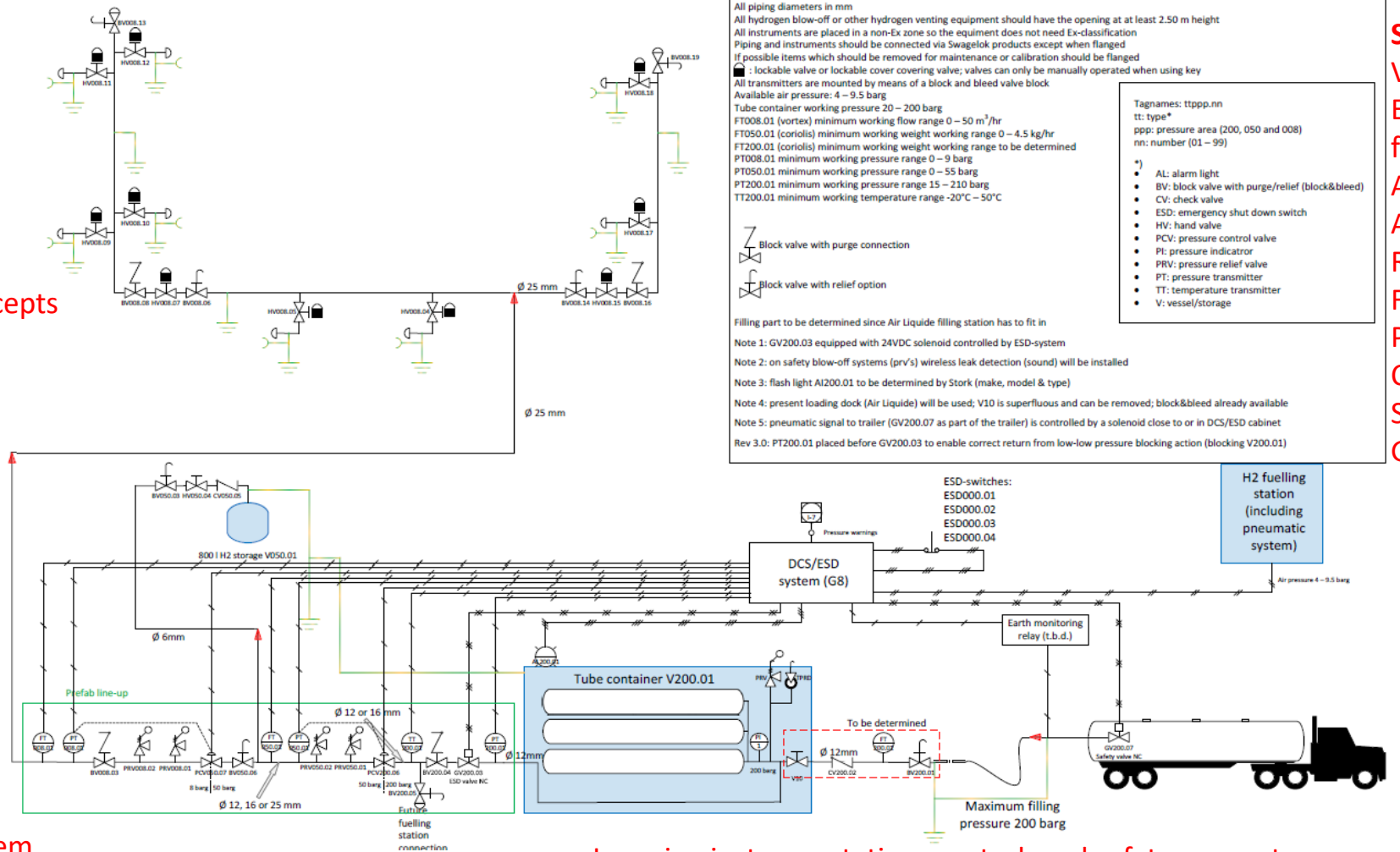
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Practical Training EnTranCe WING

Learning to safely handle H2, procedures, securing test procedures, and commissioning.

Learning components

Learning design concepts



Skills

VCA (Safety, Health, and Environment Checklist for Contractors)
ATEX (Explosive Atmosphere Regulations)
Flange assembly
Plastic welding
Couplings (e.g., Swagelok)
Gas detection meter

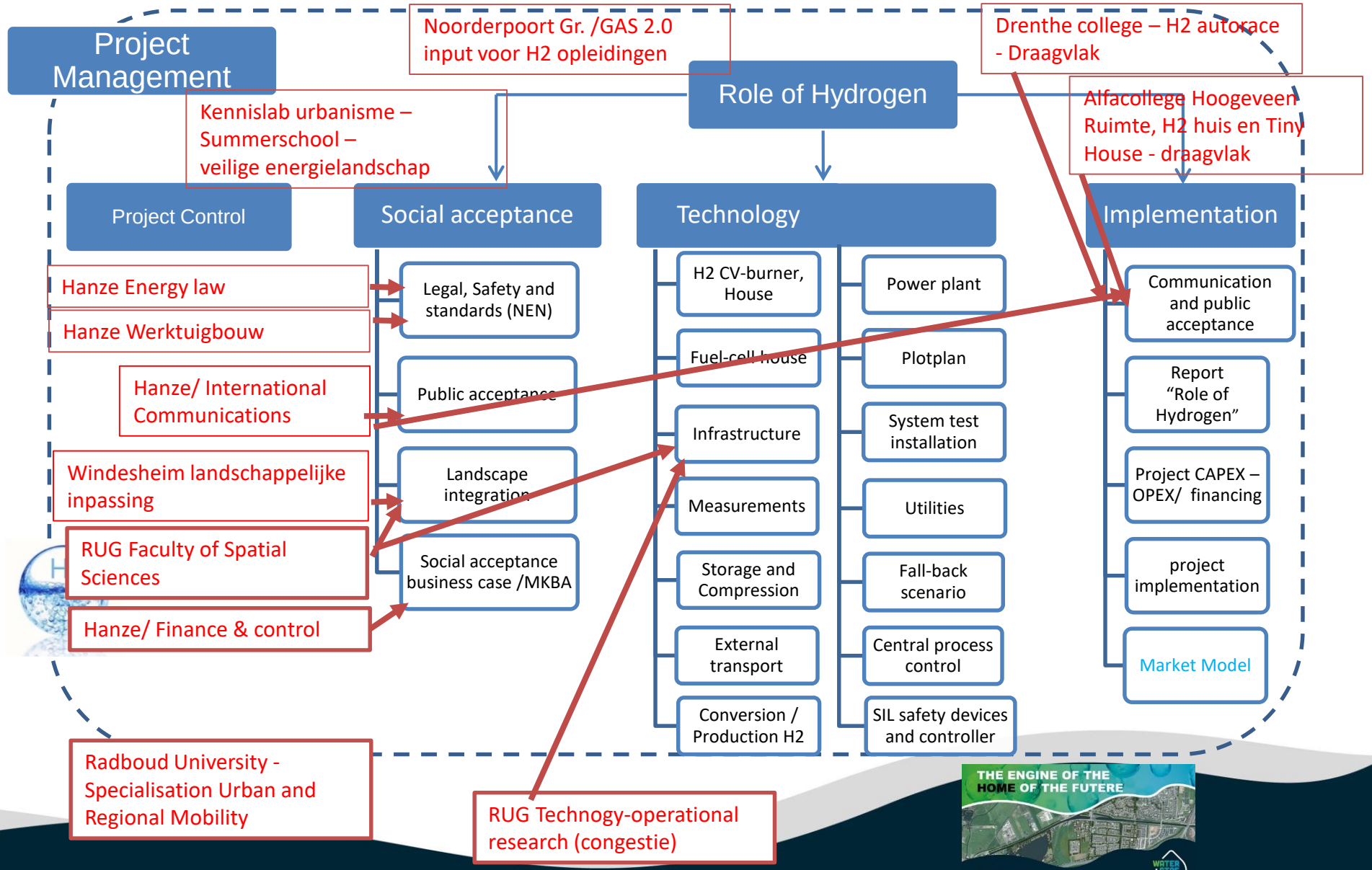


Practical work on the system

Learning instrumentation, control, and safety concepts

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Hydrogen district Hoogeveen work packages and their relationship to education

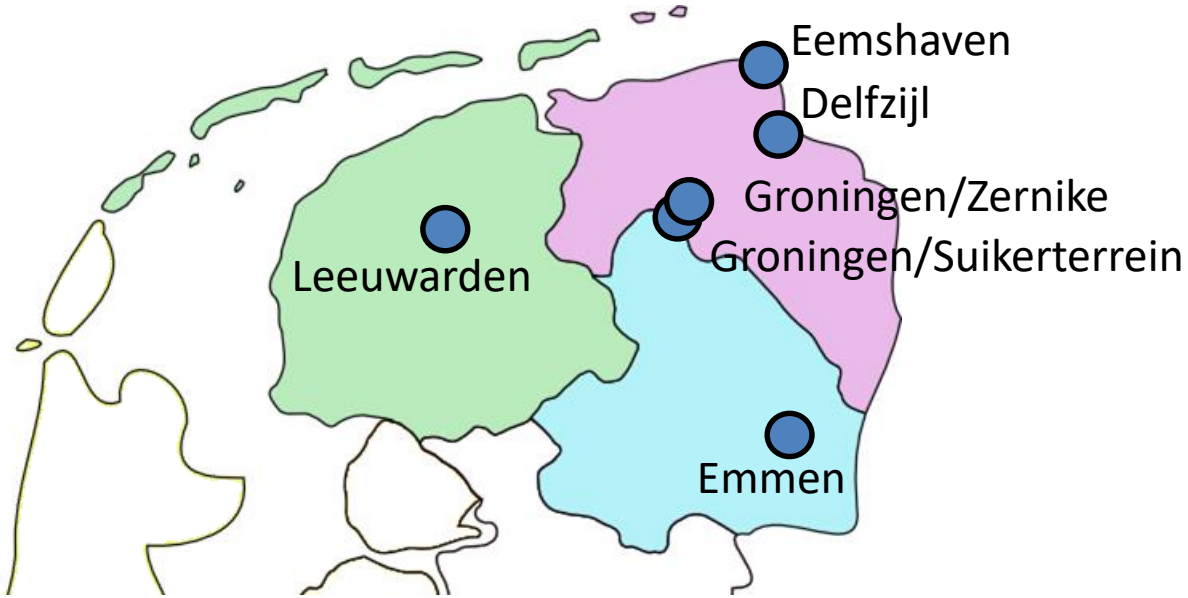


Hydrogen Valley Campus Europe HVCE

HVCE
Hydrogen Valley Campus Europe







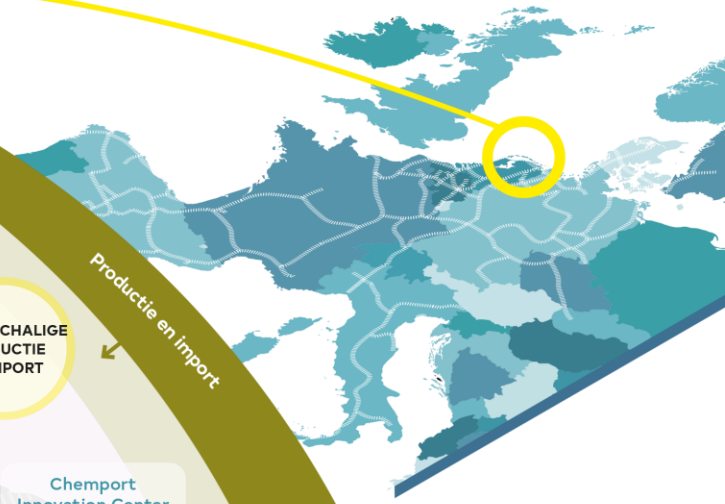
Campus partner with facilities

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HVCE
Hydrogen Valley Campus Europe

Het kennis en innovatie ecosysteem in het Noorden

- Industrie en praktische toepassing
- Test- en proeflocatie
- Opleidingshotspot



Productie en import

Distributie, opslag en keten ontwikkeling

Toepassing

Bedrijvencluster Eemshaven

GROOTSCHALIGE PRODUCTIE EN IMPORT

Campus TRNG

Chemport Innovation Center

OPSLAG EN DISTRIBUTIE

Campus Groningen

ENTRANCE

Duurzaamheidscampus Suiker

NXT Airport Groningen

WATER

Wetsus

Energie Campus

Water Campus

TOEPASSING IN DE MOBILITEIT

Resato Academy

TOEPASSING IN DE INDUSTRIE

EMMHY

GZI NEXT

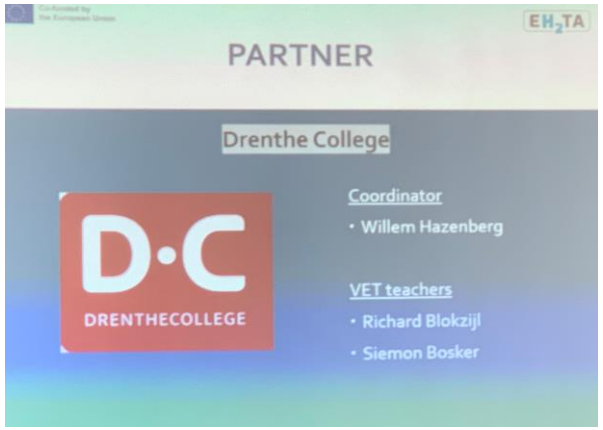
Green Wise Campus Emmen

GEBOUWDE OMGEVING

Investa Expertise Centrum

DC International Hydrogen EH_2TA









Co-funded by the European Union



EH2TA Work Packages:

- Hydrogen production and safety
- Transport and storage
- Hydrogen filling stations
- Hydrogen cars with fuel cells
- Hydrogen cars with internal combustion engines

EH_2TA
Education in Hydrogen Technologies Area

[EH2TA 1ªEdición – ERASMUS FP]

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GreenSkills4H2

The project will focus on the hydrogen value chain, and more precisely on hydrogen production, distribution, transport and storage.

- (Year 1)
  - After an analysis of the skills needs and the development of a skills strategy
- (Year 2 – Year 3)
  - A core curriculum will be drafted, and training materials will be developed
- (Year 3 – Year 4)
  - Trainings will then be implemented to test the materials developed with different publics

The GreenSkills4H2 project counts 33 partner

[Home - Green Skills for Hydrogen]



Hydrogen Centre of Vocational Excellence (H2COVE)

Upskilling Europe's Workforce for the Hydrogen Economy

H2CoVE
HYDROGEN CENTRES OF VOCATIONAL EXCELLENCE

Our Impact goals

- 150 teachers involved in "Train the Trainer" courses
- 800 business stakeholders engaged
- 1,000 employees upskilled or reskilled
- 140 students in challenge-based learning competitions
- 12 student project theses addressing real industry challenges

Co-funded by the European Union

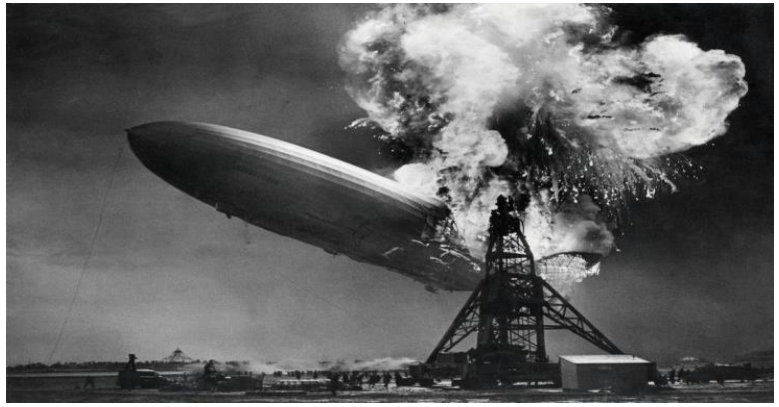






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Safety perception and reality



Hindenburg, May 6, 1937!
37 fatalities
62 survivors
Hydrogen-filled



USS Akron, US Navy, April 4, 1933!
73 fatalities
3 survivors
Helium-filled



Tenerife KLM-Pan Am, March 27, 1977
583 fatalities
61 survivors
Kerosene-filled

Last accident involving a regular airplane.
November 25 2024– **Swiftair Flight 5960**, a Boeing 737-400SF operating on behalf of DHL, crashed near a two-story house on approach to Vilnius, Lithuania, killing one of the four crew members onboard.



Questions:
Do you still fly in a regular airplane?
Could it be that we've learned something about hydrogen since 1937?
All three accidents were weather-related (two storms and one fog incident).

Safety throughout the Industry

United States Occupational Incidents in 2018

Industry	Total Incidents –Nonfatal	Incidence Rate* -Nonfatal	-Fatal
Agriculture, forestry, fishing and hunting	64.200	3,7	574
Oil and gas extraction	1.100	0,8	13
Construction	199.100	3,0	1.008
Petroleum and coal products manufacturing	900	1,3	5
Chemical manufacturing	16.100	1,9	18
Industrial gas manufacturing (hydrogen)	**200**	**1,0**	**1**
Grocery stores	86.000	4,5	38
Gasoline stations	17.100	2,4	47
Power generation, transportation & distribution	6.800	1,7	5
Investment banking and securities	1.900	0,2	4

* * Incident rate is number of incidents per 100 full time employees per year
* Data Retrieved from U.S. Bureau of Labor Statistics

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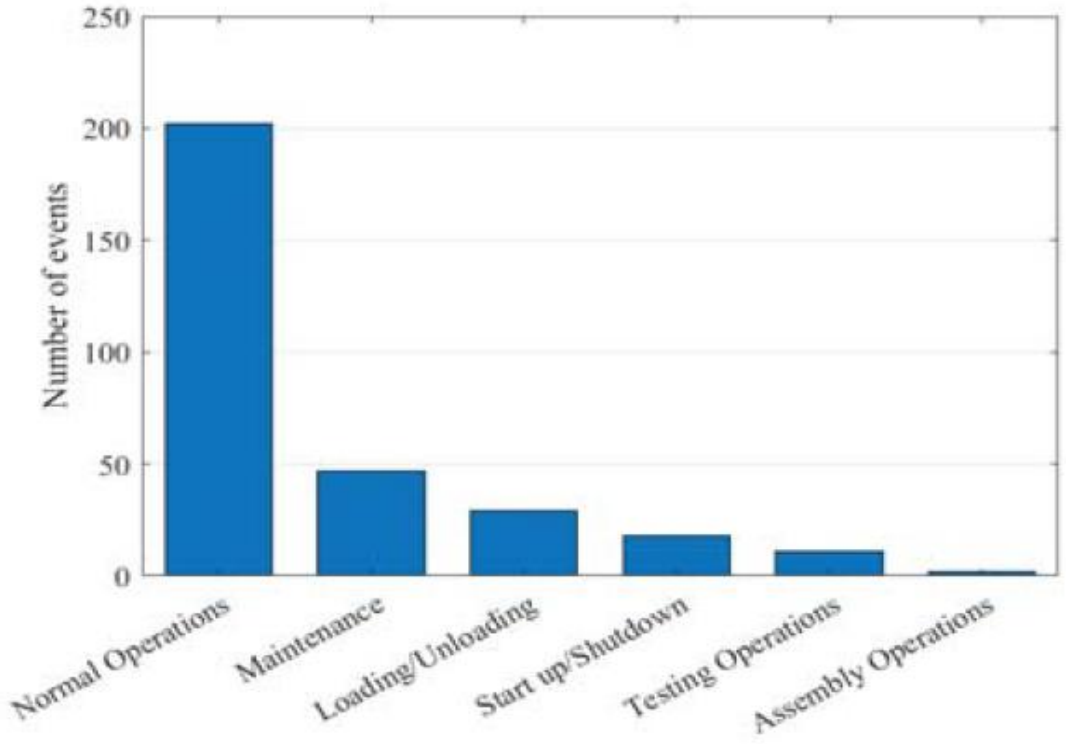
Key Questions for H2 Incident Analysis

- **Operational status of the facility at the time of the event**?
- Main initiating events causing hydrogen releases?
- **Main causes of hydrogen releases**
- In which **process component** do they happen?
- In what type of type of **activities** do accidents occur?
- During which **execution phase** did things go wrong?
- What was the **effect** of the failure?
- What type of **cause** triggered the incident?
- What were the consequences of the incident?
- Number of H2 incidents over time



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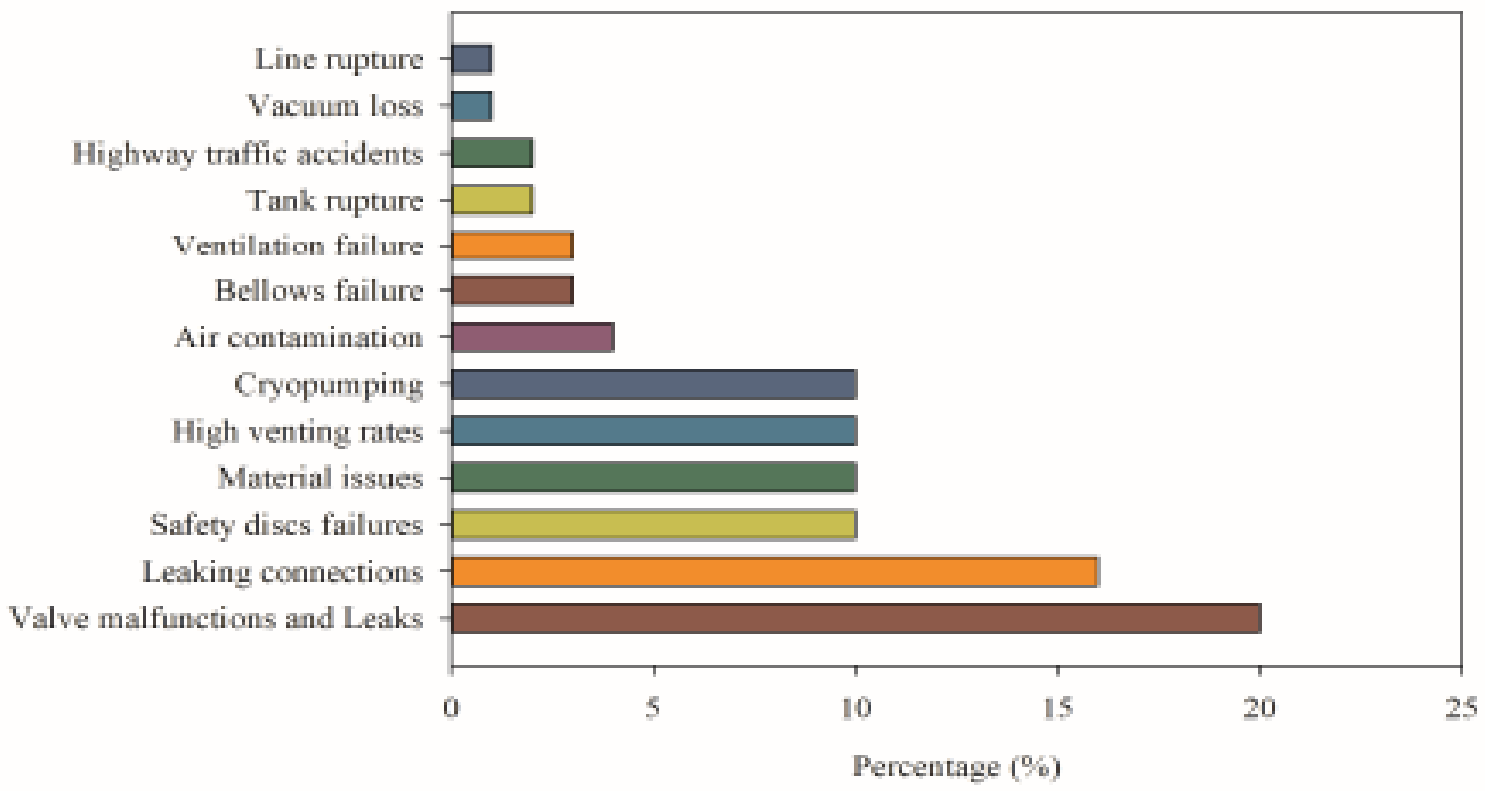
Operational status of the facility at the time of the event

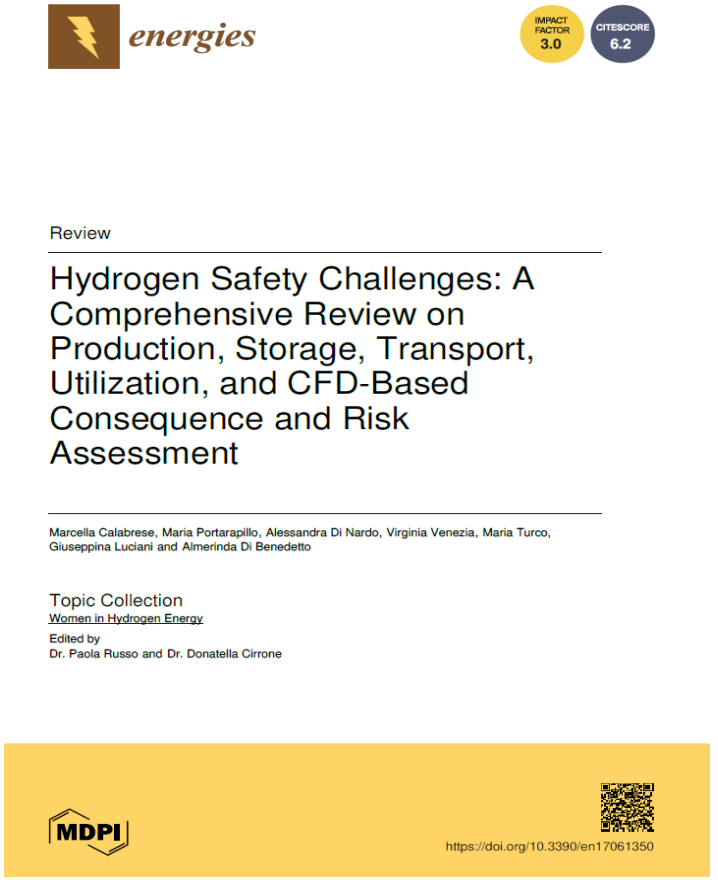


The analysis of the database through BI tools has proven that most H2-related events (i.e., 202 out of 325) occurred during the normal operations of the plants.
This is a predictable outcome since an industrial facility operates under ”normal conditions” for most of its working life.

(5) (PDF) Analyzing Hydrogen-Related Undesired Events: A Systematic Database for Safety Assessment

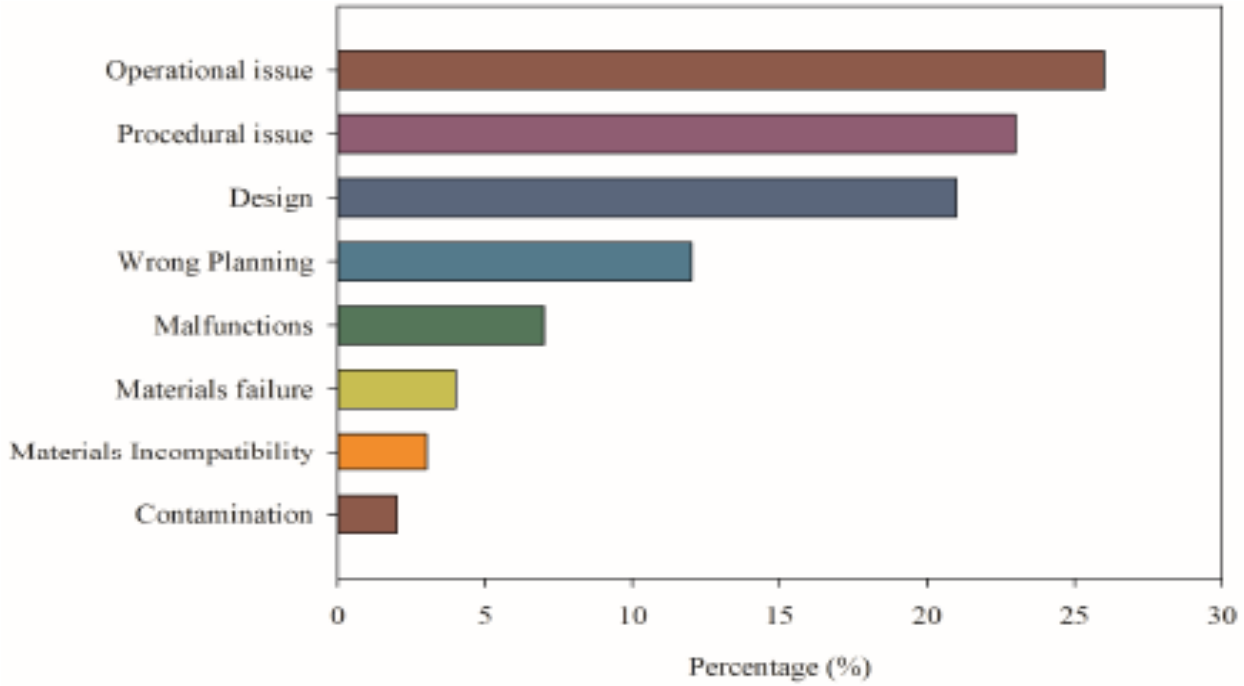
Energies HSC (2024) Main initiating events causing hydrogen releases

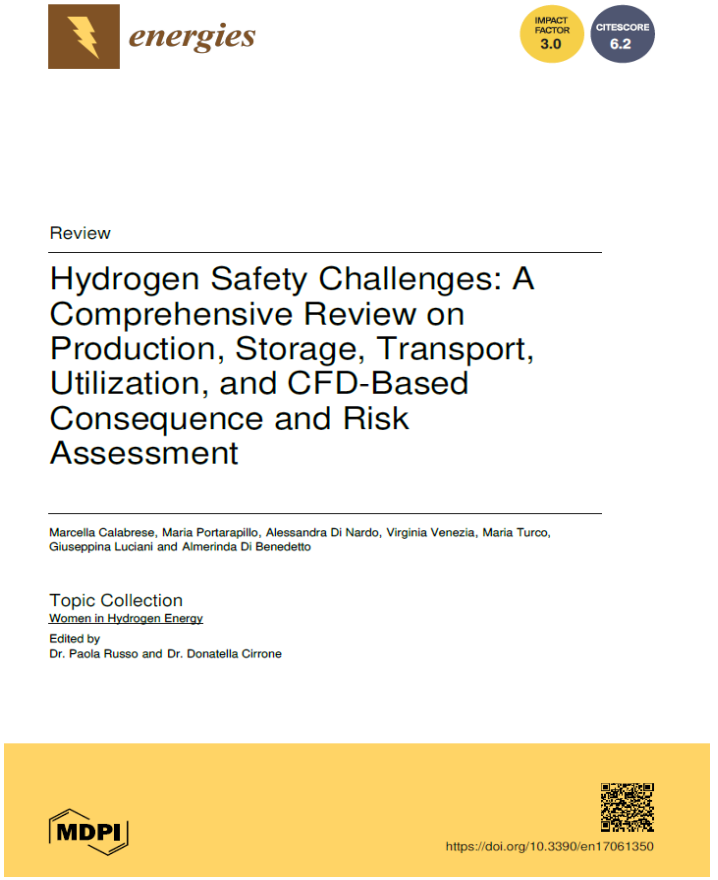




https://mdpi-res.com/d_attachment/energies/energies-17-01350/article_deploy/energies-17-01350-with-cover.pdf?version=1719152873

Energies HSC (2024) Main causes of hydrogen releases





European Gas Association EIGA Database, Brussels, Belgium. 2023. Available online: https://www.eiga.eu/ (accessed on 5 February 2024).

Causes of Incidents (Hydrogen in the Past)

Over the past decades, significant incidents have occurred related to hydrogen applications. The causes can be categorized into seven types:

1. Mechanical or material failure
2. Corrosion
3. Excessive pressure
4. Embrittlement of storage tanks
5. Boiling liquid expanding vapor explosion (N/A)
6. Rupture due to shockwaves and projectiles (N/A)
7. Human error

Lessons have been learned from these incidents, leading to the development of tests such as hydraulic pressure tests and fire tests.

Summary of Hydrogen Incidents by Equipment and Primary Cause

Equipment / Cause	Equipment Design or Selection	Component Failure	Operational Error	Installation or Maintenance	Inadequate Gas or Flame Detection	Emergency Shutdown or Response	Other or Unknown
Hydrogen Gas Metal Cylinder or Regulator		3/13/2012 4/30/1995 2/6/2013	4/26/2010	12/31/1969			3/17/1999 11/1/2001 12/23/2003
Piping/Valves	4/4/2002 2/6/2008 5/11/1999	4/20/1987 11/4/1997 12/31/1969 8/19/1986 7/27/1991 12/19/2004 2/6/2008 10/3/2008 4/5/2006 5/1/2007 9/19/2007 10/31/1980	2/7/2009	1/24/1999 2/24/2006 6/8/1998 12/31/1969 2/7/2009	9/1/1992 10/31/1980	10/3/2008	
Tubing/Fittings/Hose		9/23/1999 8/2/2004 8/6/2008 9/19/2007	1/1/1982	9/30/2004 10/7/2005		10/7/2005	
Compressor		10/5/2009 6/10/2007 8/21/2008 1/15/2019			10-5-2009	8/21/2008	
Liquid Hydrogen Tank or Delivery Truck	4/27/1989	12/19/2004 1/19/2009	8/6/2004	12/31/1969		1/1/1974	12/17/2004
Pressure Relief Device	7/25/2013 5/4/2012	1/15/2002 1/08/2007	12/31/1969				

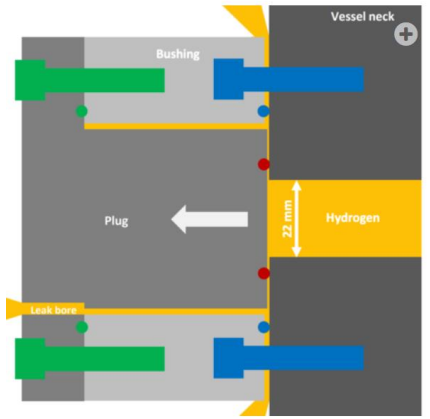
Hydrogen Safety Panel Study Table 2 Summary of Hydrogen Incidents from H2tools.org - Lessons Learned. March 2020. 69 Cases Covering the Period 1969-2019.

Color Key

xx/xx/xxxx = no ignition

xx/xx/xxxx = explosion

xx/xx/xxxx = fire



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Summary of Hydrogen Incidents by Equipment and Primary Cause (2)

Equipment / Cause	Equipment Design or Selection	Component Failure	Operational Error	Installation or Maintenance	Inadequate Gas or Flame Detection	Emergency Shutdown or Response	Other or Unknown
Instrument	1/15/2019	3/17/1999 12/31/1969 2/6/2013					
Hydrogen Generation Equipment	7/27/1999			10/23/2001			
Vehicle or Lift Truck		7/21/2011					2/8/2011 12/9/2010
Fuel Dispenser		8/2/2004 5/1/2007 6/11/2007 9/19/2007		2/24/2006 1/22/2009			
Fuel Cell Stack							5/3/2004 12/9/2010 2/8/2011
Hydrogen Cooled Generator				12/31/1969 2/7/2009			
Other (floor drain, lab anaerobic chamber, heated glassware, test chamber, gaseous hydrogen composite cylinder, delivery truck)		11/14/1994 7/21/2011	7/27/1999 6/28/2010 8/21/2008	12/31/1969 3/22/2018			6/10/2019

Hydrogen Safety Panel Study
Table 2
Summary of Hydrogen Incidents from H2tools.org - Lessons Learned.
March 2020. 69 Cases Covering the Period 1969-2019.

Color Key

xx/xx/xxxx = no ignition
xx/xx/xxxx = explosion
xx/xx/xxxx = fire

Failure Cause Distribution for Pipelines

Tabel 7.2 Faaloorzaakverdeling voor het scenario breuk voor buisleidingen met aardolieproducten.

Faaloorzaak	Faalfrequentie	Aandeel (%)
Beschadiging door derden	$7{,}19 \times 10^{-5}$	47,9
Mechanisch	$3{,}23 \times 10^{-5}$	21,5
Inwendige corrosie	$5{,}71 \times 10^{-6}$	3,8
Uitwendige corrosie	$1{,}72 \times 10^{-5}$	11,5
Natuurlijke oorzaken	$9{,}15 \times 10^{-6}$	6,1
Operationeel/overig	$1{,}38 \times 10^{-5}$	9,2
Totaal	**$1{,}5 \times 10^{-4}$**	**100**

https://omgevingsveiligheid.rivm.nl/documenten/rekenvoorschrift-omgevingsveiligheid-module-v-versie-okt-2020

Aria (2009)
Accidentology Involved Hydrogen Type of activities do

MINISTRY OF ECOLOGY, ENERGY, SUSTAINABLE DEVELOPMENT AND TOWN AND COUNTRY PLANNING



ACCIDENTOLOGY INVOLVING HYDROGEN



ARIA

Activities	On a 215 cases sample	
	Nb of cases	%
Chemical sector*	84	39
Refining / petrochemical industry*	47	22
Transport, packaging and storage	35	16
Metallurgy / metal works	17	7,9
Waste treatment / recycling	8	3,7
Nuclear industry	5	2,3

* excluding transport, packaging and storage

https://www.aria.developpement-durable.gouv.fr/wp-content/files_mf/SY_hydrogen_GB_2009.pdf

Aria (2009) Accidentology Involved Hydrogen Consequences of the failure

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ACCIDENTOLOGY INVOLVING HYDROGEN



ARIA

Consequences	On a sample comprising 213 cases with known consequences	
	Nb of cases	%
Deaths	25	12
Serious injuries	28	13
Injuries (including serious ones)	70	33
Internal material damage	183	86
External material damage	17	8
Internal operating losses	89	42
Evacuated population	8	3,8

https://www.aria.developpement-durable.gouv.fr/wp-content/files_mf/SY_hydrogen_GB_2009.pdf

OECD (2023)
Risk-based Regulatory Design For the Safe Use of Hydrogen (439 Pages)

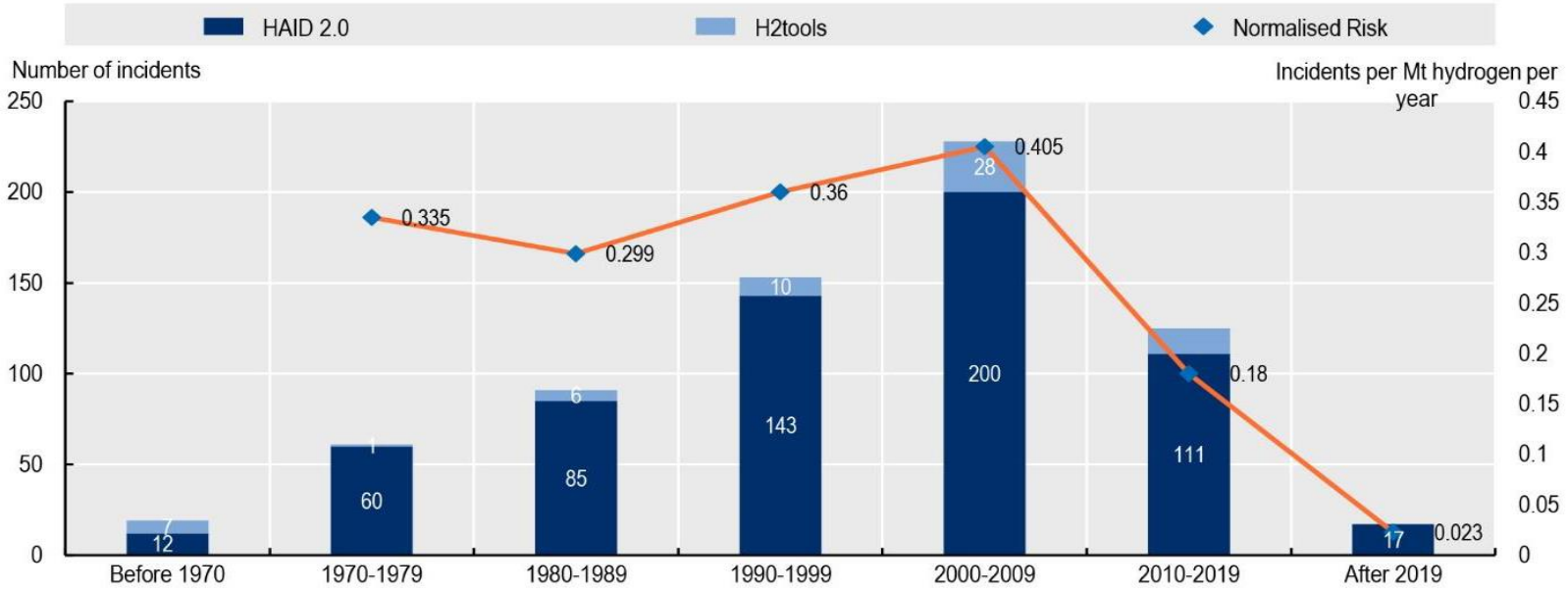


Report on Low-Emission Hydrogen Transition

- Prepared for the Dutch government; funded by the European Commission's DG REFORM.
- Aims to support the shift to widespread use of low-emission hydrogen.
- Provides recommendations on hydrogen regulation and governance.
- Analyzes six scenarios covering the hydrogen lifecycle from production to usage.
- Findings tailored to the Netherlands but may benefit other countries.

https://www.oecd-ilibrary.org/docserver/46d2da5e-en.pdf?expires=1732746921&id=id&accname=guest&checksum=5CF2253E2EC198D6F4106E3612BD33E8

OECD (2023) Number of H2 incidents over time





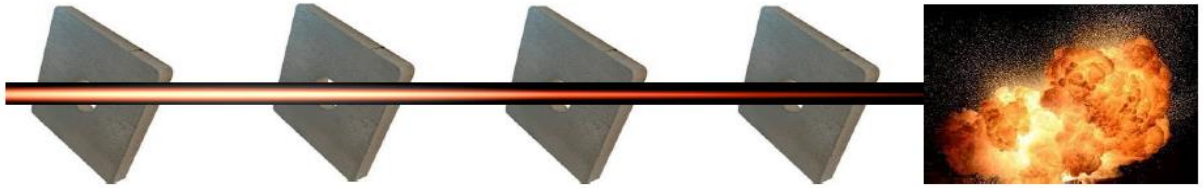
https://www.oecd-ilibrary.org/docserver/46d2da5e-en.pdf?expires=1732746921&id=id&accname=guest&checksum=5CF2253E2EC198D6F4106E3612BD33E8

Example (Event ID477) of cascading effects



Prosecutor's report on Gangeung Hydrogen Tank Explosion Accident, May 2019, South Korea
The following tekst is adapted from the English translation by INERIS about the contributing factors:

1. Oxygen removing component omitted in the system …
2. Buffer tank static spark remover was omitted during construction…
3. Operator made fault by running water electrolysis system lower than operation power level, which induced increase of O_2 concentration…
4. 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.
5. Safety management team did not follow



Hydrogen tank explosion kills 2 in Gangneung - The Korea Times

WCM World Class Maintenance Hydrogen Boreas

The 5 Research Themes:

1. Failure Mechanisms and Lifespan Expectations
2. Maintenance Concepts and Design for Maintenance
3. Competencies (Led by DCterra/Bilfinger and Shell)
4. Autonomous Operation
5. Chain Integration

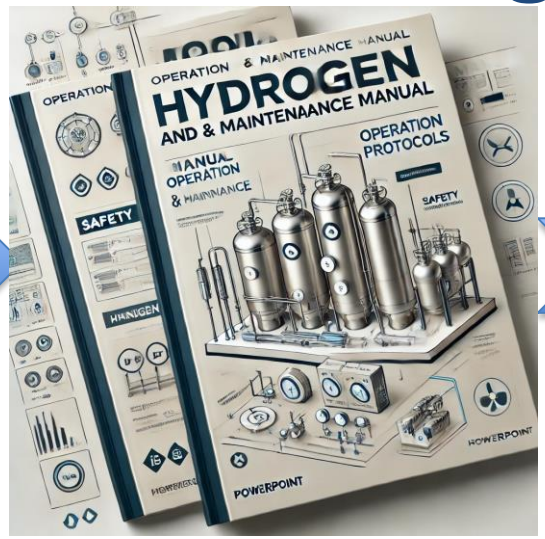
Cluster:	1	2	3	4	5	6
Gasunie	1	2				3
Equans	2	1			3	
Douna		1		3		2
HYCC						
Spie						
Shell	3	2	1			
Stork	3	2	1			
Advisian	2	1			3	
WCM			1	3		2
ABB		1	3		2	
KIWA						

Field lab HYDRO-BOREAS

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Challenges with Supplier Documentation and Impact on Educational Programs







- **Suppliers promote their systems as the best solution**
  - Often claiming that **little maintenance is required**
- **Consequences:**
  - **Manuals describe only a limited number of inspections**
  - **Manuals are often under an NDA**, making it difficult to share experiences
- **Link to Educational Programs**
- **Need for comprehensive training programs** to address gaps in documentation
- **Developing skills** to effectively perform maintenance with limited information
- **Encouraging knowledge sharing** and best practices within education and industry

Accident reports → Failure Risks → Inspection Plan →Maintenance plan → Competencies

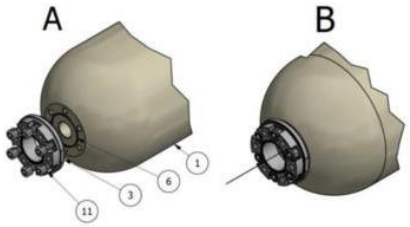


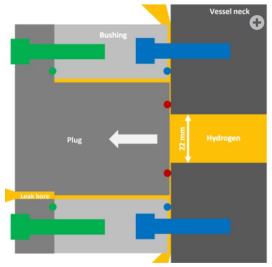












Accident reports provide background information on the cause of the incident. With this information, we can ask ourselves the following questions:

1. Could we have prevented this incident through a specific inspection regime, and what should we have done?
2. What does this mean for our maintenance regime, and what adjustments are needed in the procedures and educational programs?

Failure Risks → Competencies ← Autonomous Plant

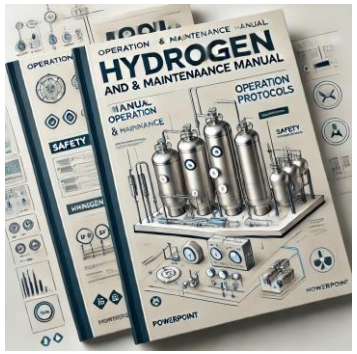
Hydrogen Tools



SAFEN

Field lab HYDRO-BOREAS





Field lab HYDRO-BOREAS



Field lab HYDRO-BOREAS



- The failure behavior of hydrogen installations and the degree of autonomy in hydrogen plant operations affect the competencies students must acquire, thereby influencing curriculum content.

Facts about SAFEN

- **SAFEN is a Joint Industry Project (JIP) where 15 partners work together to:**
- Close knowledge gaps in understanding failure mechanisms, hazards, and accident situations in renewable technologies involving hydrogen, ammonia, and CCS (carbon capture and storage).
- Develop risk-based methodologies for hydrogen, ammonia, and CCS facilities.
- Set up an environment for sharing of knowledge and data that enables continuous development of best practices for safe design technologies under the scope.
- **The partners include consultancies, energy companies / asset owners, technology providers, and authorities.**
- **SAFEN Phase 1 started in March 2022 and was completed in August 2023.**
- **Phase 2 of the project was kicked off this fall and is planned to be completed in 2025.**

WVIP Hydrogen and Safety

The WVIP's objective is to facilitate and accelerate the broad introduction of hydrogen as an innovative and sustainable energy carrier. We achieve this by identifying and addressing potential risks, as well as controlling these risks by taking appropriate precautionary measures. Below you will find an overview of all our publications, divided into the various work packages.

https://nlhydrogen.nl/overzicht-publicaties/

1. WP 1 Guidelines for permit issuance
2. WP 2 Risk management and incident response
3. WP 3 Legislation, regulations, and policy
4. WP 4 Safety aspects and risks of hydrogen
5. WP 5 Risk analysis for hydrogen usage

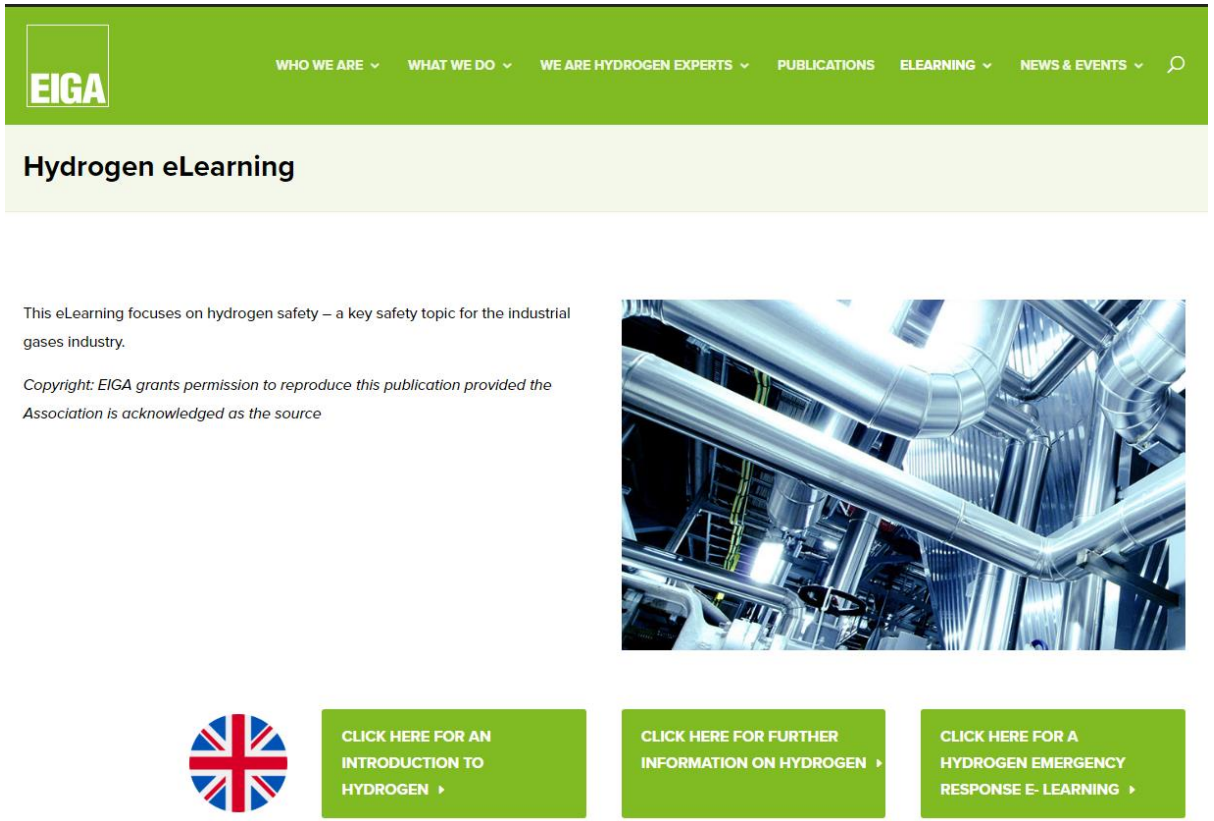
- The above work packages can be further developed within LLO (Lifelong Learning) to create teaching materials from these reports. WP1 and WP3 align well with Entrance (Energy Law), and WP2, WP4, and WP5 could be integrated into both secondary vocational (MBO) and higher professional education (HBO).

WVIP Hydrogen and Safety Studies

- Enkele voorbeelden zijn:
- Hanze = **WP1 Vergunningproces waterstoftankstations**
- Hanze = **WP1 Leidraad inpassing waterstoftankstations in bestemmingsplannen**
- Noorderpoort – Alfa = **WP2 Handreiking veilige leefomgeving: waterstofaggregaten**
- Noorderpoort = **WP4 Tubetrailer in schip**
- Noorderpoort = **WP4 Transportmethoden H2 over de weg**
- DCTerra = **WP4 Inventarisatierapportage Hydrogen bunkering, guidelines, procedures en checklists**
- DCTerra = **WP5 HAZID studie Case 3 Lokale productie van waterstof bij een waterstoftankstation.**

In total, this includes 38 studies and reports, allowing everyone to select those that align with their educational focus.

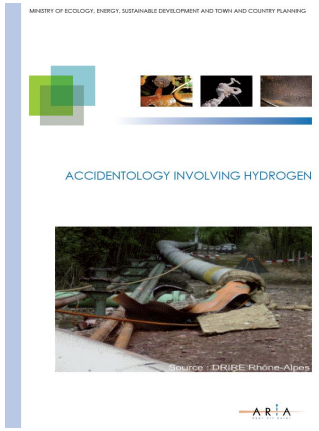
Eiga (2024) Hydrogen e-learning



[Hydrogen eLearning - EIGA : European Industrial Gases Association]

https://www.eiga.eu/

Aria (2009) Accidentology Involved Hydrogen



Over 70% of accidents involving hydrogen and whose causes are known are due to organisational and human failure alone or coupled with an equipment failure.

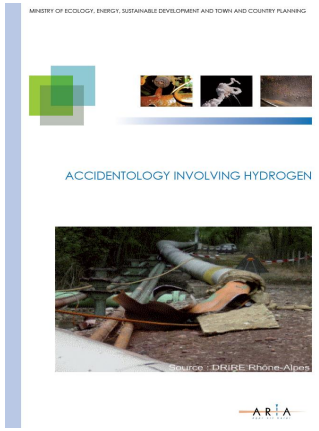
All stages in the service life of a facility are concerned : design), safety report, operation, maintenance, modifications, intervention.

Hydrogen accidentology highlights two main causes of accidents involving organisational and human factors : **maintenance or upkeep operations and process management errors**.

Out of the 25 mortal accidents recorded in the ARIA database, 48% occurred during maintenance operations. The figure is 100% if only the five French accidents are taken into consideration

https://www.aria.developpement-durable.gouv.fr/wp-content/files_mf/SY_hydrogen_GB_2009.pdf

Aria (2009) Accidentology Involved Hydrogen

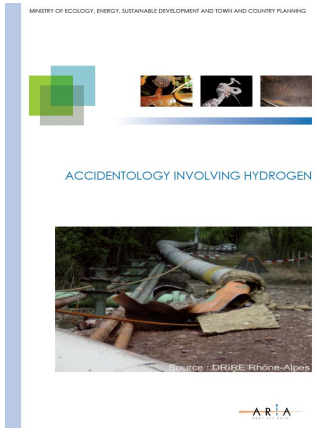


Among the accidents involving **maintenance** as the main cause include:

- Maintenance operations at hot spots without ensuring the absence of an explosive atmosphere beforehand;
- Errors or wrong commissioning of facilities during maintenance operations;
- Rinsing of equipment without a detailed risk analysis; •
- Poorly conducted operations (errors in joint assembly or bolt tightening, etc.) resulting in hydrogen leaks),
- Electrical or automatism failures following maintenance

https://www.aria.developpement-durable.gouv.fr/wp-content/files_mf/SY_hydrogen_GB_2009.pdf

Aria (2009) Accidentology Involved Hydrogen

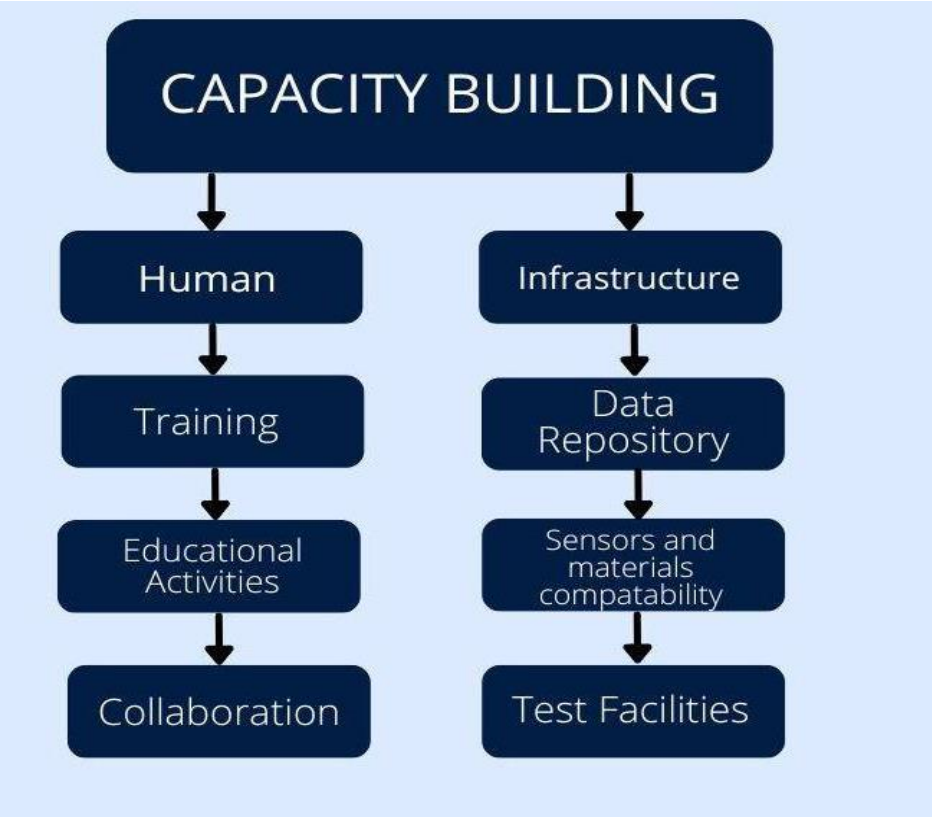


The implementation of a **high-performance safety management** tool should allow hydrogen risks to be curtailed especially due to:

- Adapted operating, maintenance and emergency procedures, understood and applied by the technicians,
- Preventive maintenance of equipment,
- Rapid detection of malfunctions,
- Optimal training of technicians,
- Increased risk awareness in the facility given the permanent risk of ignition due to hydrogen.

https://www.aria.developpement-durable.gouv.fr/wp-content/files_mf/SY_hydrogen_GB_2009.pdf

CoE Process safety India (2009) CAPACITY BUILDING



The successful adoption of a Hydrogen economy requires sufficient skilled workforce for the hydrogen.

Appropriate training of the workforce & other stakeholders-emergency responders, regulators, is essential to eliminate barriers

Dissemination of guidelines will help updating industry to create units of competency and qualifications with the growth of infrastructure

https://icgh.in/ppt/Chitra.Rajagopal_4D.pdf

2023 Analyzing Hydrogen-Related Undesired Events: A Systematic Database for Safety Assessment

Table 1. Comparison of the existing hydrogen safety data collection tools

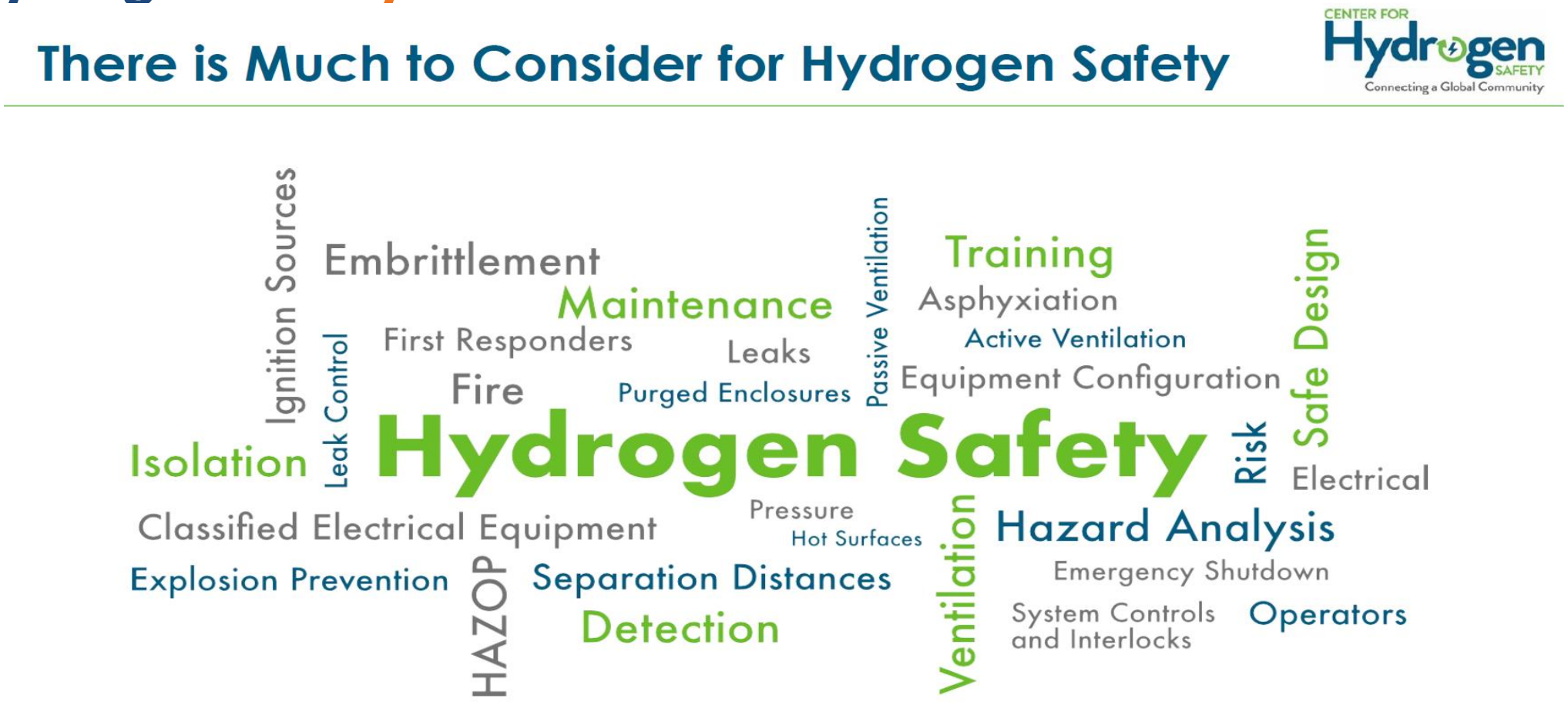
General feature	HIAD 2.0	H_2Tools	NREL CDPs	CHS Failure Rates
Records collected	655 events	221 events	44 fueling stations	Unknown
Year of creation	2004	2006	2020	Under development
Public access to data	Yes	Yes	Partial	Unknown
Initiating event	Yes	Yes	Yes	Yes
Location	Partial	No	Yes	Yes
Type of application	Yes	Yes	Yes	Yes
Primary cause	Yes	Yes	Yes	No
Contributing causes	Partial	Yes	Yes	No
Release size	Yes	No	Partial	Yes
Operating conditions	Yes	Yes	Yes	Partial
Components involved	Yes	Yes	Yes	Yes
Component size	Partial	No	Partial	Yes
Site inventory	No	No	Yes	Partial
Confinement	Yes	No	No	Yes
Failure symptoms	No	Yes	No	No
H_2 detection	No	No	Yes	Partial
Ignition	Yes	Yes	No	Yes
Consequences	Yes	Yes	Yes	Partial
Mitigation systems	No	No	No	Yes
Lessons learned	Yes	Yes	Yes	No
Recurrence frequency	No	Yes	No	No
Maintenance	No	No	Yes	Partial
Regular reporting	No	No	Yes	Yes
Data quality check	No	No	Yes	Unknown

Large Databases on Hydrogen Safety

- HIAD
- H2tools
- NREL CSP's
- CHS Failure Rates

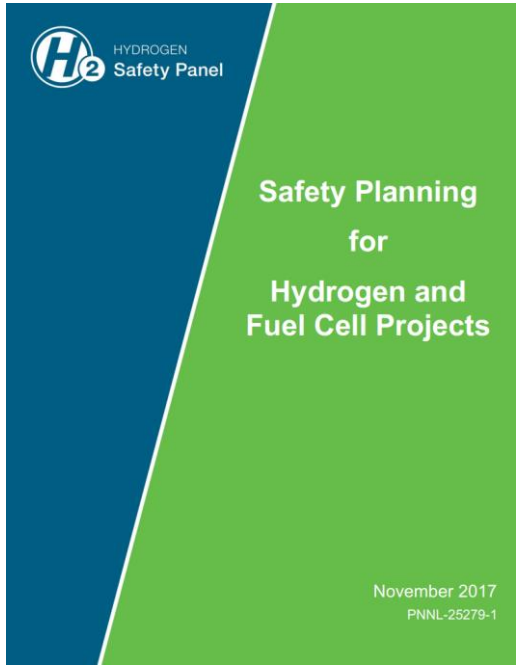
(5) (PDF) Analyzing Hydrogen-Related Undesired Events: A Systematic Database for Safety Assessment

Center for Hydrogen Safety (2022) there is Much to consider for Hydrogen Safety



https://eec.ky.gov/Energy/Documents/Slides-Nick%20Barilo.pdf

H2Tools (2017) Safety planning for Hydrogen and Fuel cell projects



[Safety_Planning_for_Hydrogen_and_Fuel_Cell_Projects-November2017]

1. Description of Work
2. Organizational Safety Information
    - Organizational Policies and Procedures
    - Hydrogen and Fuel Cell Experience
3. Project Safety
    - Identification of Safety Vulnerabilities (ISV)
    - Risk Reduction Plan
    - Operating Procedures - Operating steps - Sample handling and transport
    - Equipment and Mechanical Integrity
    - Management of Change Procedures
    - Project Safety Documentation
4. Communication Plan
    - Personnel Training
    - Safety Reviews
    - Safety Events and Lessons Learned
    - Emergency Response o Self-Audits
5. Other Comments or Concern

H2Tools (2020) Hydrogen incidents Examples

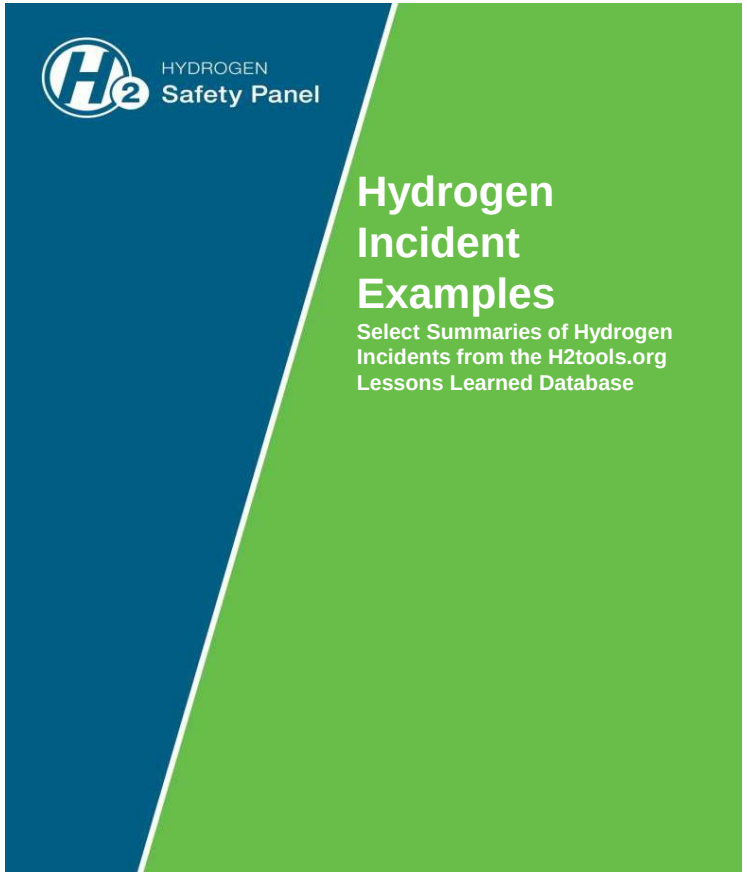


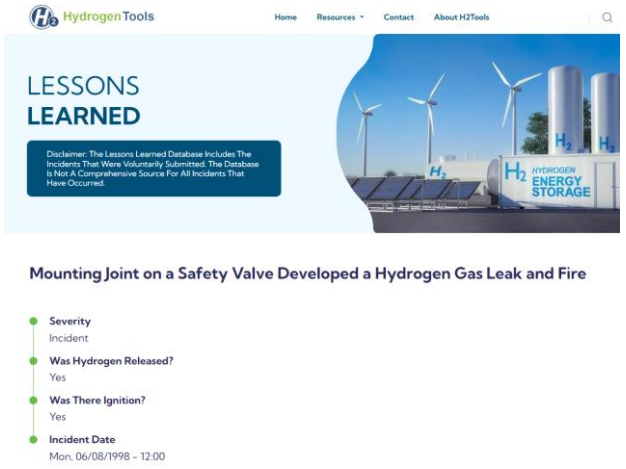
Table 1. Incident Category Links

Category	Starts on Page	No. of Incidents
A. Pressure Relief Device Incidents	4	4
B. Hydrogen Cylinder Incidents	6	7
C. Piping Incidents	9	11
D. Liquid Hydrogen Incidents	15	6
E. Hydrogen Instrument Incidents	18	3
F. Industrial Truck Incidents	20	3
G. Hydrogen Compressor Incidents	22	2
H. System Design, Operation and Maintenance Incidents	23	9
I. Laboratory Incidents	27	10
J. Fueling Station Incidents	32	12

https://h2tools.org/sites/default/files/Hydrogen_Incident_Examples.pdf

H2Tools (2020) Hydrogen incidents Examples





Causes

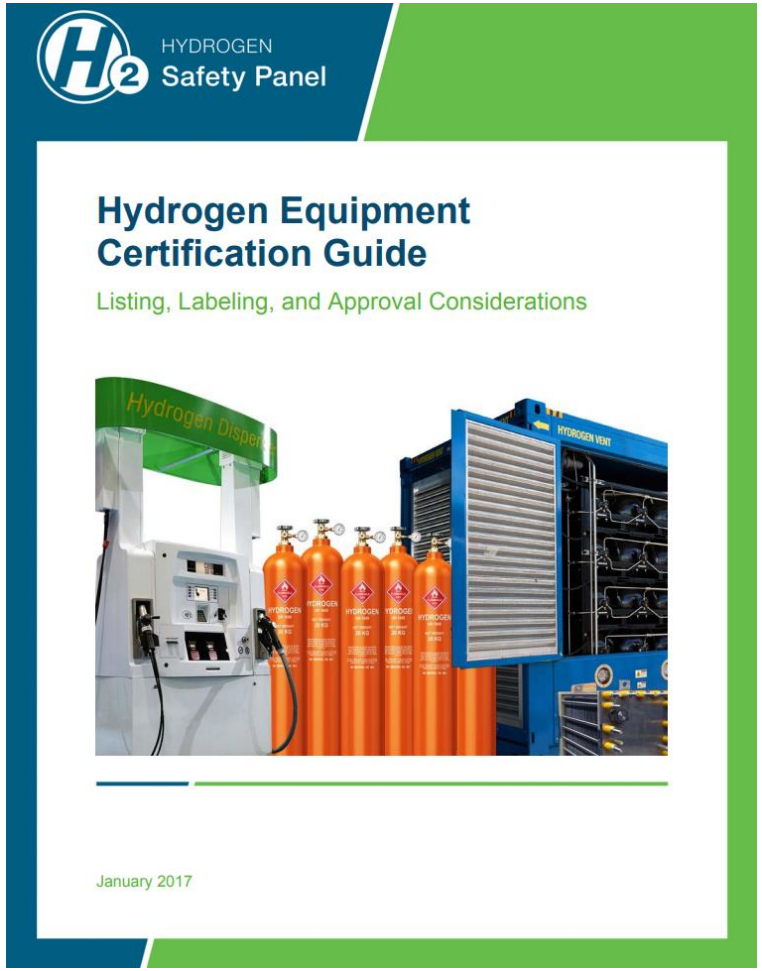
An incorrectly sized gasket, which was smaller than the original gasket was used in a joint of a safety valve at the time of a turnaround shutdown. This caused an unbalanced force across the valve and an unequal tightness of the connecting bolts. Due to the small size of the gasket and looseness of bolts, the weight of the piping was applied locally to the joint, and the joint inclined gradually. Eventually un-reacted hydrogen blew out from a gap due to the inclination, and it was ignited by static electricity sparks.

Lessons Learned

Construction errors are difficult to detect once construction is complete. It is important to develop and use a systematic oversight process for minimizing construction errors during the construction process.

[Mounting Joint on a Safety Valve Developed a Hydrogen Gas Leak and Fire | H2tools | Hydrogen Tools]

H2Tools – Hydrogen Equipment certification Guide

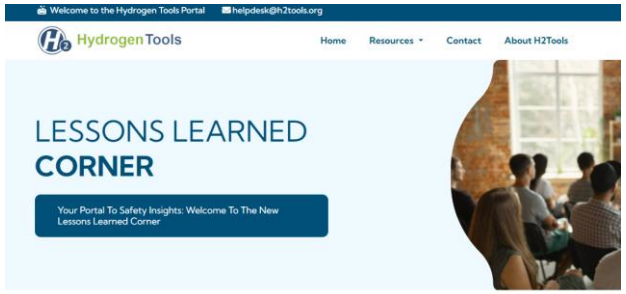


The purpose of this guide is to assist users of codes and standards that apply to hydrogen application and use in understanding and applying the approval, certification, listing, and labeling provisions of the codes and standards, in any application where the required certification, listing, and labeling of services, methods, or equipment has not yet been established or achieved.

2017 (228 pagina's) Geen formele overheidsstatus

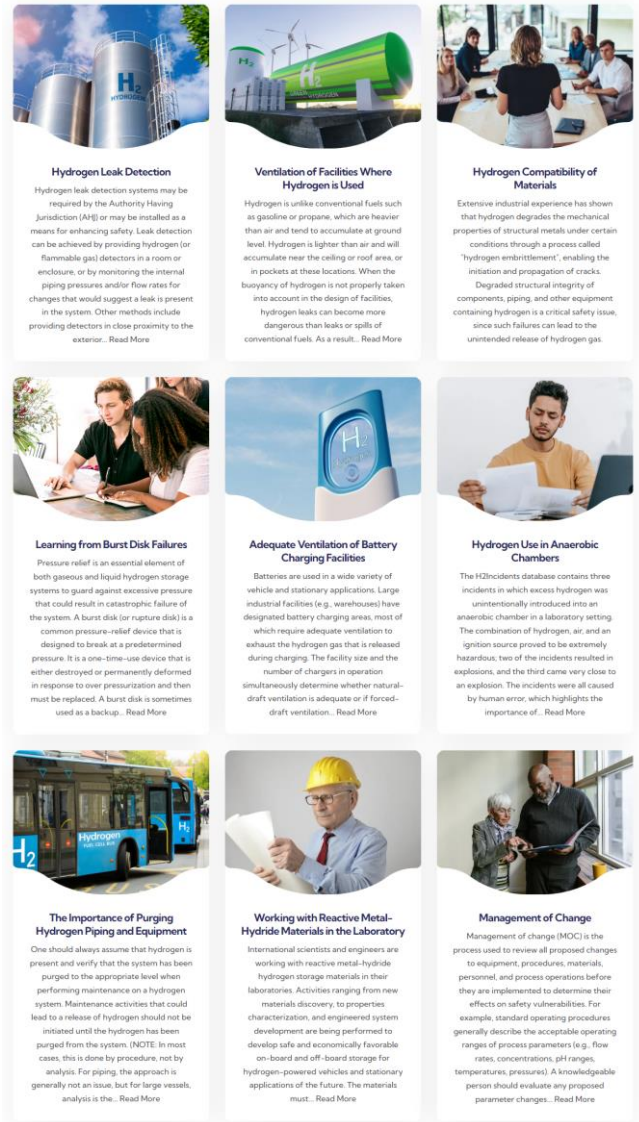
This guide was prepared as an account of work sponsored by an agency of the United States Government.
Certification Guide for 2016 NFPA 2 DRAFT

H2Tools – Lessons Learned corner – H2LL



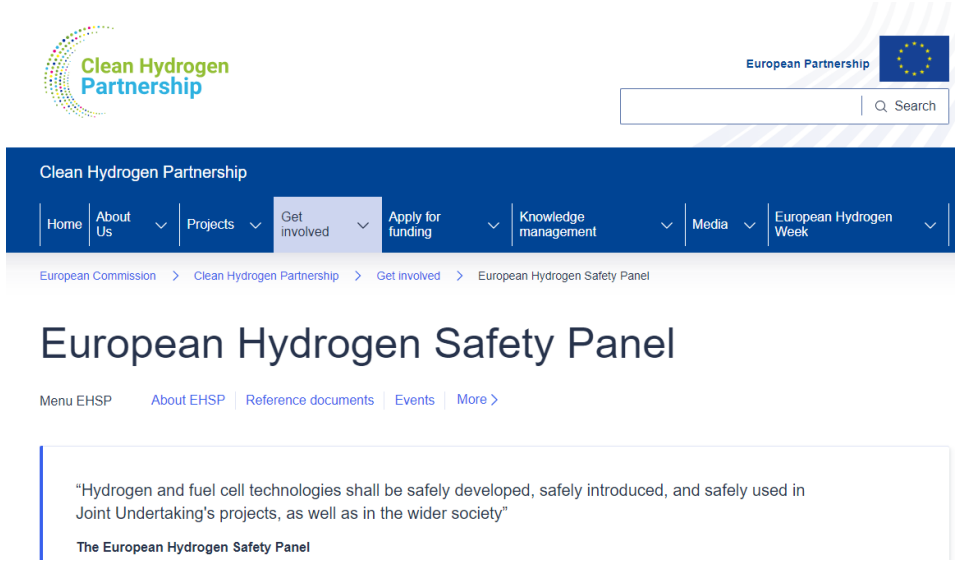


This H2LL database is supported by the U.S. Department of Energy. The safety event records have been contributed by a variety of global sources, including industrial, government and academic facilities.
H2LL is a database-driven website intended to facilitate the sharing of lessons learned and other relevant information gained from actual experiences using and working with hydrogen.
Key themes from the H2Incidents database will be presented here and several safety event records will be highlighted to illustrate the relevant lessons learned.



[Hydrogen Technologies Safety Guide]

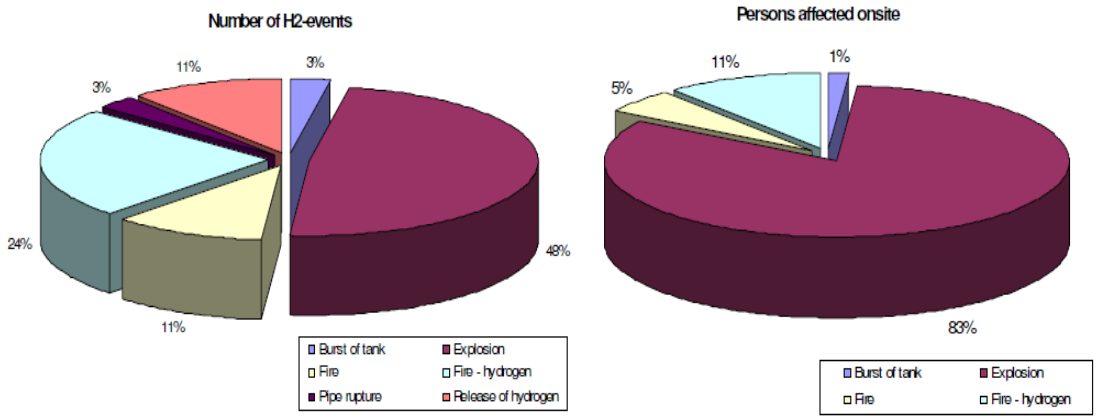
H2Tools – European Hydrogen Safety Panel



Hydrogen and fuel cell technologies shall be safely developed, safely introduced, and safely used in Joint Undertaking's projects, as well as in the wider society
The European Hydrogen Safety Panel

Hydrogen systems can be as safe as systems based on conventional energy carriers, provided the specific properties of hydrogen and the hydrogen system are properly addressed. To this end, it is important to disseminate knowledge, competence and safety culture to all stakeholders in the technological value chain: design, manufacturing, assembly, operation, maintenance, decommissioning, first responders, training, education, etc.
European Hydrogen Safety Panel - Clean Hydrogen Partnership
Get in contact with the EHSP by email at **EHSP@clean-hydrogen.europa.eu**

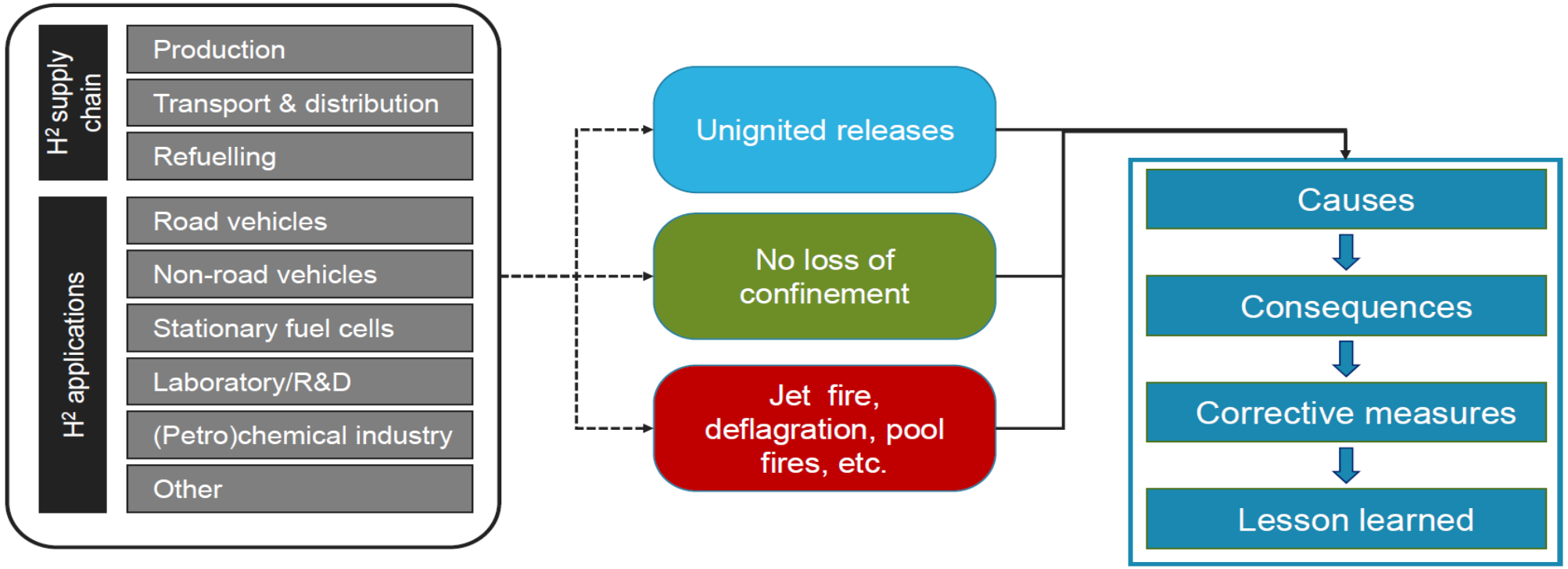
HIAD 2 Hydrogen Incident and Accident database



The Hydrogen Incident and Accident database (HIAD) was designed in order to represent a reliable multi-task open communication platform for safety lessons learned and risk communication, as well as a potential data source for risk assessment. The database was developed within the framework of the NoE HySafe and the last release is available online since 2010. HIAD is intended to become the up-todate repository of any accidental event related to hydrogen technology.

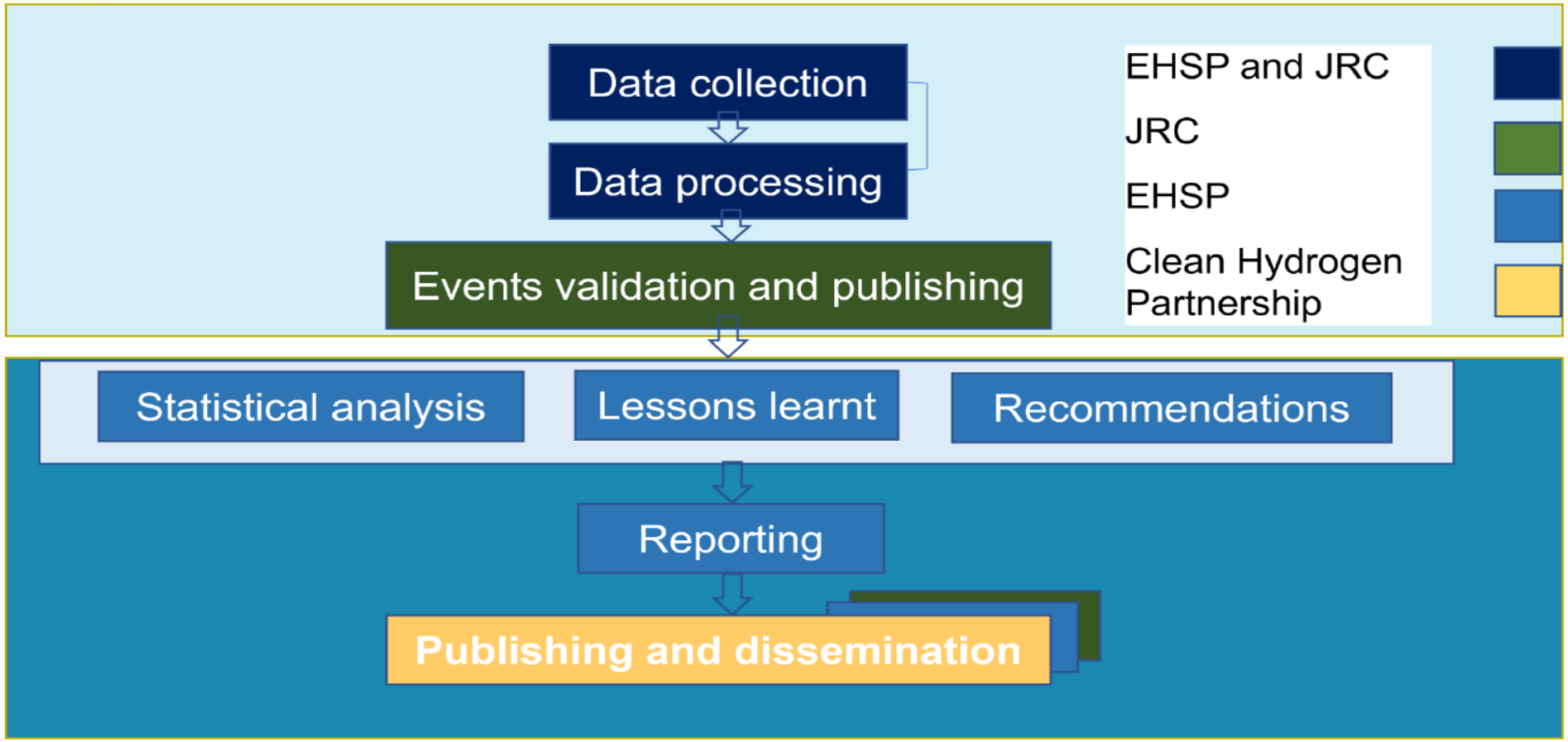
https://h2tools.org/sites/default/files/2019-08/paper%20%28HIAD%29.pdf

HIAD 2 Hydrogen Incident and Accident database structure



fhttps://www.clean-hydrogen.europa.eu/system/files/2022-06/Analysis%20of%20hydrogen%20incidents%20and%20accidents%20database%20HIAD%202.0%20%28ID%2013831425%29.pdf

HIAD 2 Overview of the data collection and Assessment process



https://www.clean-hydrogen.europa.eu/system/files/2022-06/Analysis%20of%20hydrogen%20incidents%20and%20accidents%20database%20HIAD%202.0%20%28ID%2013831425%29.pdf

DOE Hydrogen Program's safety activities

The DOE Hydrogen Program's safety activities, led by the Office of Energy Efficiency and Renewable Energy, focus on system safety in DOE-sponsored research and development (R&D) activities and in the marketplace. DOE's safety R&D activities are focused on developing hydrogen sensors for detecting hydrogen leaks. In addition, all DOE-funded hydrogen projects are required to follow DOE's Safety Guidelines and undergo review by DOE's Hydrogen Safety Review Panel to ensure safety in the operation, handling, and use of hydrogen systems.
Safe practices in the production, storage, distribution, and use of hydrogen are an integral part of future plans. Like most fuels, hydrogen can be handled and used safely with appropriate sensing, handling, and engineering measures. The aim of this program activity is to verify the physical and chemical properties of hydrogen, outline the factors that must be considered to minimize the safety hazards related to the use of hydrogen as a fuel, and provide a comprehensive database on hydrogen and hydrogen safety.

https://www.hydrogen.energy.gov/program-areas/safety

CENTER FOR Hydrogen SAFETY
Connecting a Global Community











Hydrogen & Fuel Cells Emergency Response Education Resource



35628 2020 Hydrogen safety cource
HFC_ER_Training_June_2020

HFC_ER_Training_June_2020.pptx

OECD (2023) Risk-based Regulatory Design For the Safe Use of Hydrogen) – Scenario-based accident data review and analysis

13 Scenario-based accident data review and analysis

- **Scenario 1 –** Production: Leakage from pipes connected to elektrolysers
- **Scenario 2 –** Transport pipelines: Leakage from high-pressure pipeline
- **Scenario 3 –** Road Transport: Hydrogen leakage in confined spaces/ built environments
- **Scenario 5 –** Mobility and partially confined spaces: accidents at a hydrogen refueling stations.

https://www.oecd-ilibrary.org/docserver/c058c2fe-en.pdf?expires=1732746782&id=id&accname=guest&checksum=255E72AA4979FA238315B4D



OREDA – OFFSHORE & ONSHORE RELIABILITY DATA

What is OREDA ?

- A project organization with between 7-11 oil and gas companies as members that has been running for more than 43 years.
- A comprehensive databank of reliability data collected on Topside and Subsea equipment from offshore and onshore operations in the North Sea, GOM, WOS, Angola, Adriatic, Caspian, etc.
- A forum for exchange and development of reliability methods and know-how within the oil and gas industry, production of ISO Standards and API.
- The cradle of ISO 14224, ISO 20815 and ISO TR 12489.
- For non-members access to the data was via OREDA handbooks of pre-analysed selected data, with the last version (6th edition) published in 2015.
- Non-members can now access the same format of data digitally through Software-a Service (SaaS) at OREDA@Cloud.
- .

https://



OREDA – OFFSHORE & ONSHORE RELIABILITY DATA

OREDA

Offshore Reliability Data Handbook

4th Edition

Published by: OREDA Participants

Prepared by: SINTEF Industrial Management

Distributed by: Det Norske Veritas (DNV)

Taxonomy no	Item
1.1	Machinery Compressors

Population	Installations	Aggregated time in service (10^6 hours)		No of demands
		Calendar time *	Operational time †	
131	38	3.8235	2.4253	82472

Failure mode	No of failures	Failure rate (per 10^6 hours).					Active rep.hrs	Repair (manhours)		
		Lower	Mean	Upper	SD	n/τ		Min	Mean	Max
Critical	**595***	**0.00**	**166.07**	**839.82**	**361.26**	**155.62**	**17.8**	**0.5**	**29.3**	**1818.0**
	595†	**0.08**	**268.58**	**1176.02**	**459.51**	**245.33**				
Abnormal instrument reading	3*	0.00	1.11	4.88	1.91	0.78	7.0	16.0	16.5	17.0
	3†	0.00	6.03	29.41	12.28	1.24				
Breakdown	5*	0.01	1.28	4.17	1.51	1.31	61.5	25.5	367.0	1481.0
	5†	0.00	6.20	34.23	17.26	2.06				
Erratic output	12*	0.00	6.00	29.41	12.36	3.14	32.2	3.0	56.8	580.0
	12†	0.00	9.41	43.25	17.34	4.95				

https://www.nri.ac.ir/Portals/0/images/Technology/OandM/document/OREDA.pdf



Hydrogen knowledge center

Established by the Institution of Gas Engineers and Managers (IGEM), the Hydrogen Knowledge Centre is a one-of-a-kind digital library that is designed specifically for those working and studying in the future energy field.
The goal of this resource is to share essential research, so we can aid the advancement of hydrogen learning globally and support the transition to a net zero carbon emissions future.
We work towards this goal by capturing new and existing knowledge from around the world and consolidating it into one easy-to-access platform.
Our aim is to empower industry professionals, policy influencers, students and academics who work across the wide variety of roles within the future energy space. We're here to provide access to the latest hydrogen information you need to keep up with industry innovation, progress in your career, and help you to contribute to the important developments taking place across the industry. Ultimately, this resource was created to share knowledge and to offer the latest hydrogen research, as it emerges, from projects across the UK and internationally.

Hydrogen Knowledge Centre You Tube video IGEM HNC Hydrogen Knowledge Centre - Digital Repository Dedicated to the Advancement of Hydrogen Learning

Knowledge Center for Explosion and Hydrogen Safety

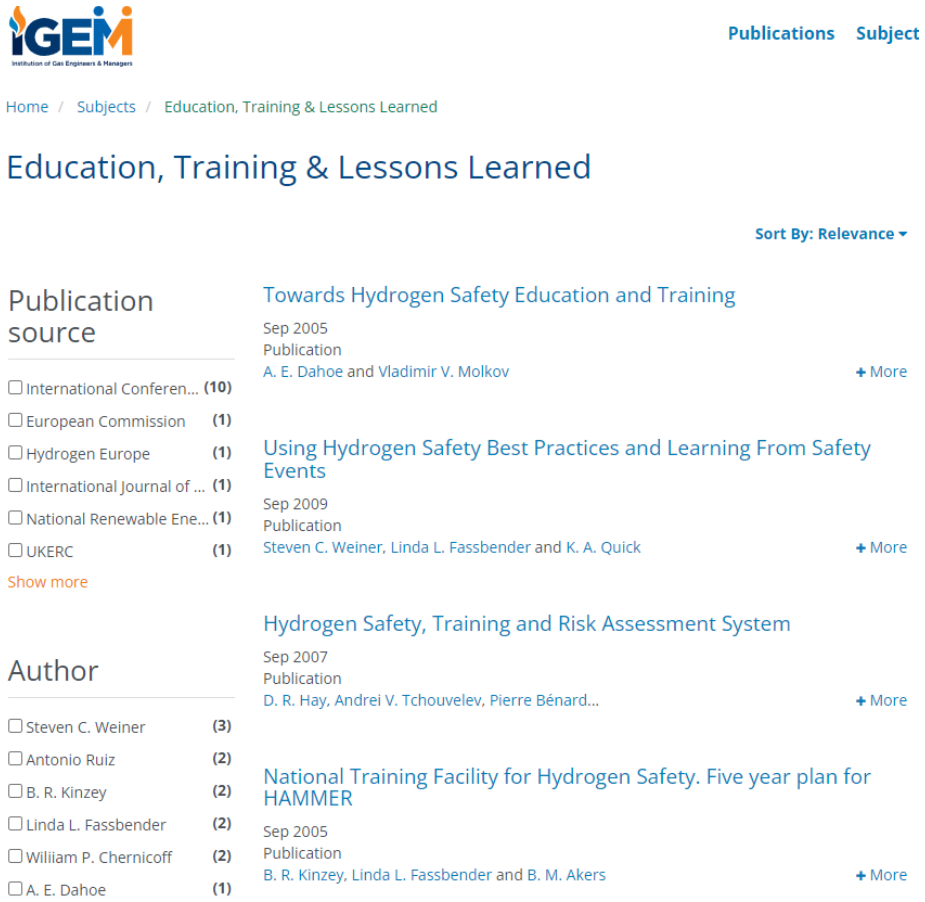
Knowledge Center for Explosion and Hydrogen Safety (KCEHS) focuses on advancing safety in explosion-prone and hydrogen-rich environments through research, training, and safety standards.

Core Services:

- **Research & Development:** Studies on explosive substances and hydrogen safety innovations.
- **Training Programs:** Certification in risk analysis, ATEX regulations, and emergency response.
- **Safety Standards:** Guidelines for handling, storage, and transport compliance.
- **Incident Analysis:** Framework for reporting and learning from explosion-related events.
- **Collaboration:** Partnerships with industries, regulators, and educational institutions.

Led by Dr. A.E. Dahoe and Ing. D.W.G. Arentsen, KCEHS offers publications, research workshops, and expert guidance. Visit their website: explosionsolutions.org.

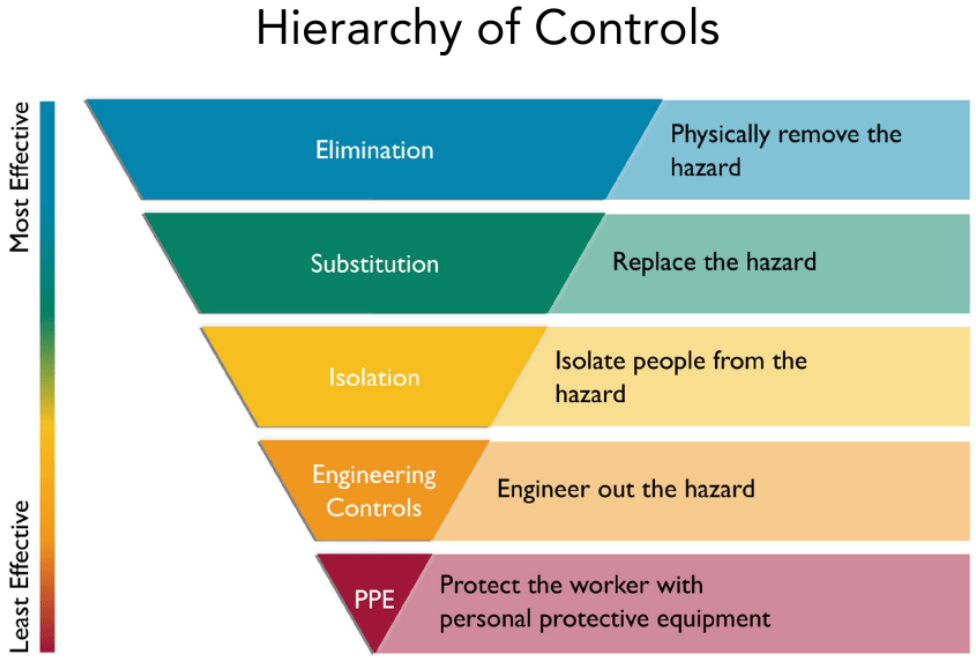
IGEM - Knowledge Center Education, Training & Lessons learned



The Hydrogen Knowledge Centre by the Institution of Gas Engineers & Managers (IGEM) was developed with support from the Department of Business, Energy and Industrial Strategy (BEIS), as part of its Energy Innovation Fund. This unique resource collects and organizes an impressive range of hydrogen research and thought pieces into one place, which makes it easy for users to access and utilize.

Education, Training & Lessons Learned | Hydrogen Knowledge Centre

Hierarchy of controls

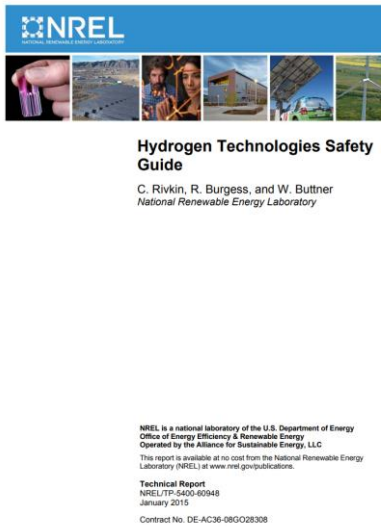


- Hierarchy of Controls in mitigating workplace risks, emphasizing the framework's effectiveness across various hazard types. It covers strategies from elimination and substitution to personal protective equipment usage, showcasing real-world examples and highlighting the importance of continuous improvement and innovation in safety measures..

[How to Apply the Hierarchy of Controls to Different Types of Risks]



NREL 2015- Hydrogen Technology Safety Guide



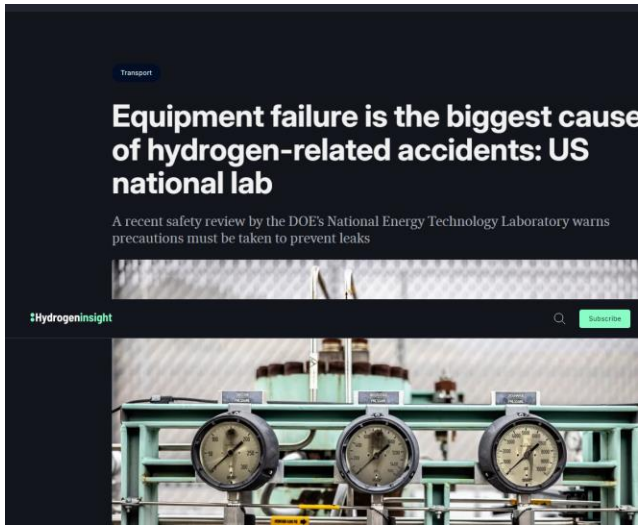
[Hydrogen Technologies Safety Guide]

Other technology-related causes such as design flaws, material incompatibility or otherwise inadequate equipment represent a combined 13.3% of the probable causes for these incidents.

“Roughly half of reported incidents have involved pressure vessels, piping, and valve systems, and to a lesser extent compressed gas canisters, electrical issues, and measurement sensor failures,” noted NETL in its report.

Meanwhile, for the 435 reports that identified contributing factors, equipment failure was only cited in 4.8% and design flaws in 7.4%, while human error, lack of situational awareness and other related operational or procedural problems were more commonly raised.

Equipment failure is the biggest cause of hydrogen-related accidents: US national lab (1)

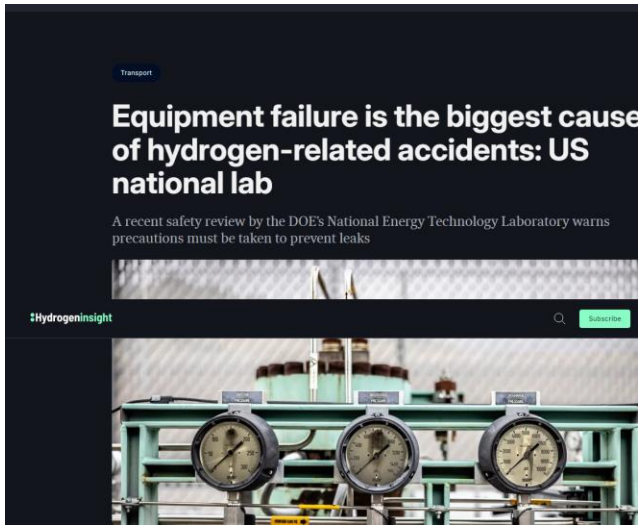


Equipment failure was the most commonly identified probable cause of nearly 350 reported hydrogen-related incidents in the US over the past 17 years, according to a report reviewing H_2 safety by the Department of Energy's National Energy Technology Laboratory (NETL).

Based on information reported on a voluntary basis to the government's H2Tools website since its launch in 2006, equipment failure specifically was cited in 25.9% of 347 reports that included a probable cause, compared to around 9.8% blaming human error, the second most commonly reported cause.

https://www.hydrogeninsight.com/transport/equipment-failure-is-the-biggest-cause-of-hydrogen-related-accidents-us-national-lab/2-1-1505699?zephr_sso_ott=Yu4pMP

Equipment failure is the biggest cause of hydrogen-related accidents: US national lab (2)



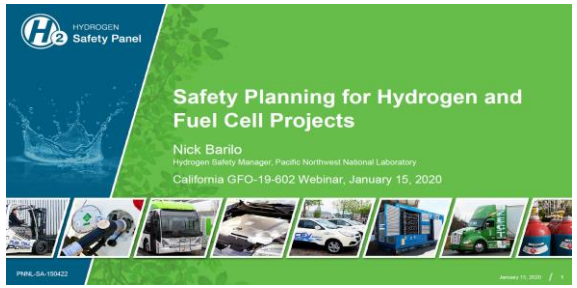
https://www.hydrogeninsight.com/transport/equipment-failure-is-the-biggest-cause-of-hydrogen-related-accidents-us-national-lab/2-1-1505699?zephr_sso_ott=Yu4pMP

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Hydrogen Safety Panel (US) The Safety Challenge





- Safety issues must be addressed for successful hydrogen technology acceptance and deployment
- Safety issues can be a “deal breaker”
- Hydrogen technology stakeholders may not be able to identify and effectively address all safety issues
- Stakeholders benefit from an independent and experienced hydrogen safety review (ISR) resource involved in early design and safety planning activities.

https://www.energy.ca.gov/sites/default/files/2020-01/GFO-19-602_2020-01-15-1pm_Presentation_Safety_Planning_Webinar_ADA.pdf

NFPA 2023 Hydrogen Technologies code

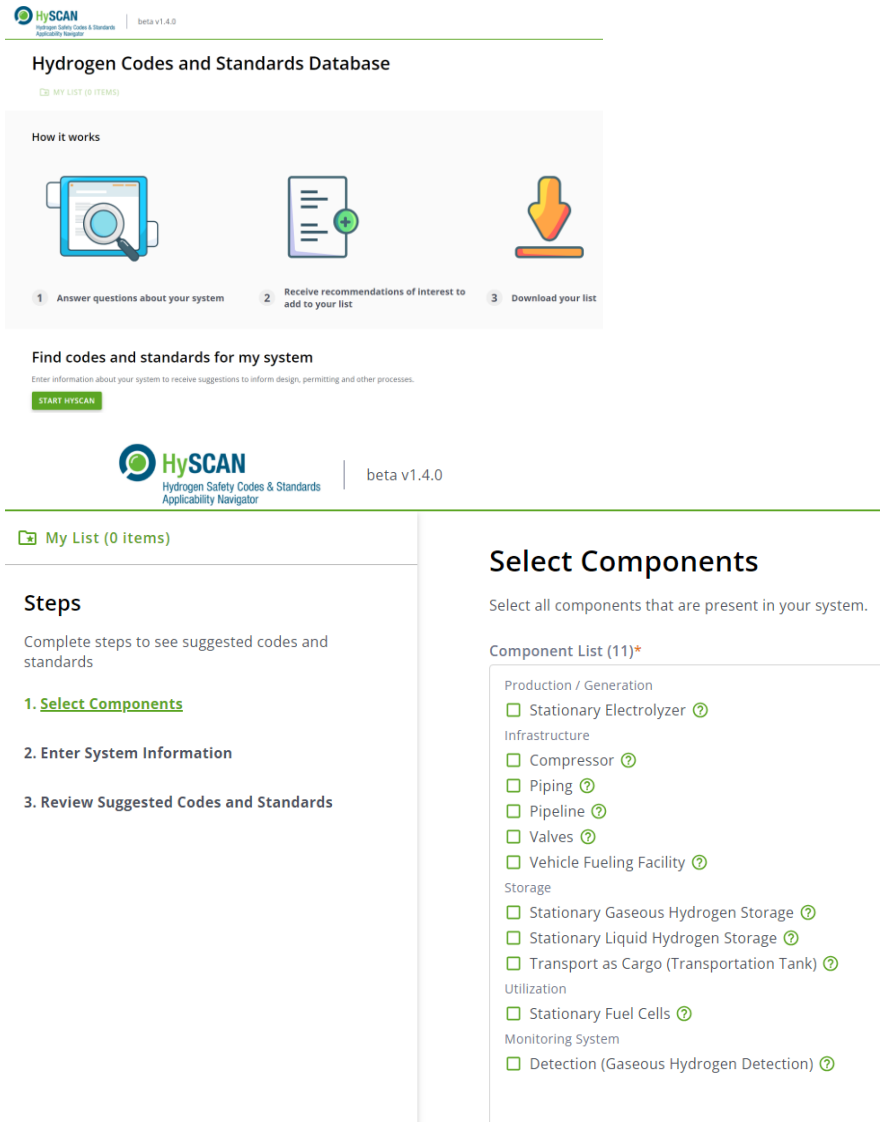
This code provides fundamental safeguards for the generation, installation, storage, piping, use, and handling of hydrogen in compressed gas (GH2) form or cryogenic liquid (LH2) form.

NFPA 2, *Hydrogen Technologies Code*, is the quintessential resource for building inspectors, engineers, installers, facility managers, and anyone else who deals with hydrogen, as it offers safeguards for its use in both gas and liquid forms.

[Buy NFPA 2, Code]



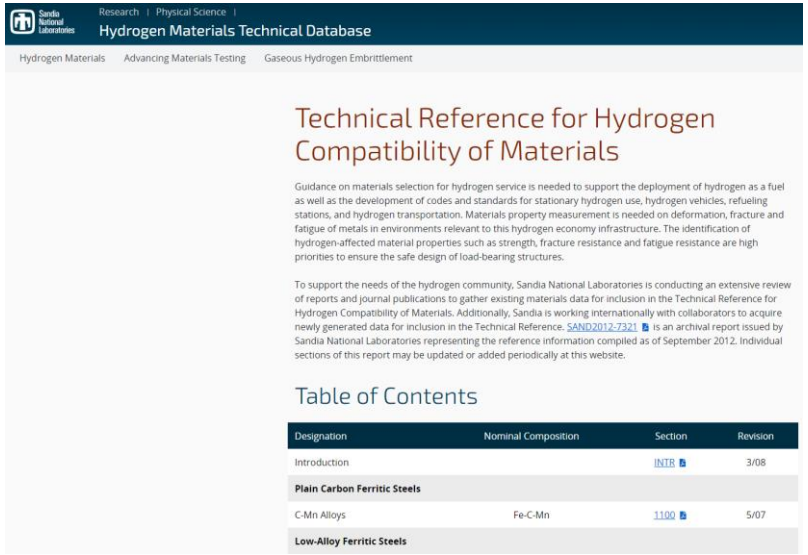
HyScan Hydrogen Safety Codes & standards Application Navigator



HySCAN Overview
Purpose: Identifies hydrogen-specific codes and standards (focused on NFPA 2).
Scope: Highlights applicability and relevant chapters, not detailed requirements.
Limitations: Not exhaustive; full texts may be copyrighted.
Audience: Tailored to U.S. stakeholders; guides informed discussions.

HySc
an

Technical Reference for Hydrogen Compatibility of Materials



[Hydrogen Materials Technical Database – Sandia National Laboratories]

Technical Reference for Hydrogen Compatibility of Materials

Purpose:

Guidance on material selection for hydrogen service to support hydrogen fuel deployment and development of safety codes and standards.

Focus Areas:

- Deformation, fracture, and fatigue of metals in hydrogen environments.
- Identification of hydrogen-affected material properties (strength, fracture resistance, fatigue resistance).
- Ensuring safe design for load-bearing structures in hydrogen infrastructure.

Sandia National Laboratories' Contribution:

- Comprehensive review of existing materials data from reports and journal publications.
- Collaboration with international partners to acquire and update new data.

Applications:

Hydrogen vehicles, refueling stations, stationary hydrogen use, and hydrogen transportation.

Greenwise Campus

- Greenwise Campus is the premier network for knowledge development, innovation and entrepreneurship. Companies, educational organizations and public authorities join forces here. Together, we work on smart, green solutions for today and tomorrow.
- Tracks
  - Circulair Plastics
  - Energy
  - Smart Manufacturing
  - Welfare Health Care & Technology

D·C
DRENTHECOLLEGE

Greenwise Campus - Energy

- **The challenge**
- We are switching from fossil fuel to renewable energy sources such as sun, wind, and green gas. This transition comes with new technologies, new skills and other ways of working. Our challenge is to help schools, companies and students to embrace these new sources of energy.
- Energy – Greenwise

Greenwise Campus - Energy

Gemeente Emmen koopt oude busremise. 'Er komt een sexy Willie Wortel-gebouw voor terug'

Jan Willem Horstman en Pim Siegers · 23 maart 2023, 14:23 · Drenthe Deel dit artikel



Wetenschapper Vincent Voet is met zijn onderzoeken naar duurzame kunststoffen een van de uithangborden van Stenden in Emmen. In de toekomstige regiocampus moeten meer ontdekkingen en ontwikkelingen plaats gaan vinden binnen de gemeentegrenzen. Foto: Jan Anninga

De gemeente Emmen tikt 2,4 miljoen euro af om de oude busremise te bemachtigen. Daarmee is een verschil van inzicht met de huidige eigenaren ten einde.

Het bestaande plan om op de plek van de voormalig busremise langs de Dordsestraat een nieuw innovatiecentrum met scholen en bedrijven te vestigen blijft ongewijzigd. Toch komt die gewenste regiocampus van het Drenthe College, NHL Stenden, de Rijksuniversiteit Groningen, provincie Drenthe en de gemeente Emmen maar moeizaam van de grond.





Greenwise Campus

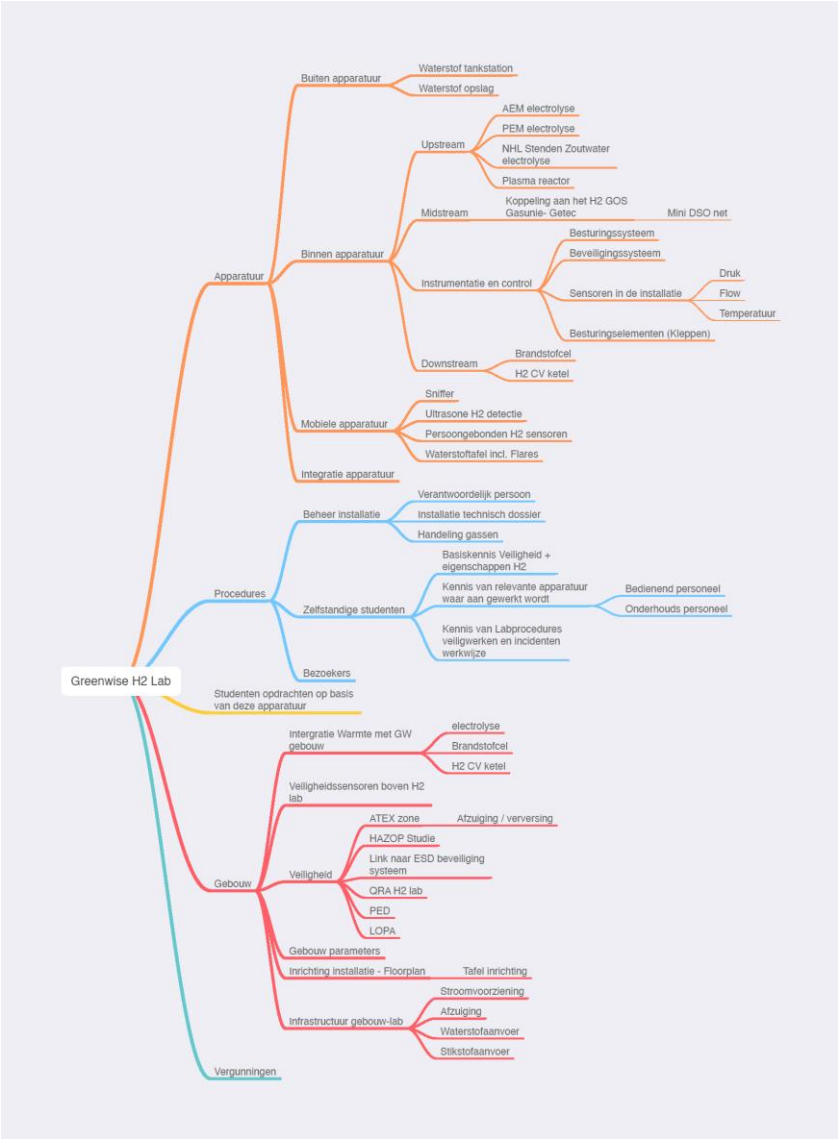


Vlekkenplan
Spotplan

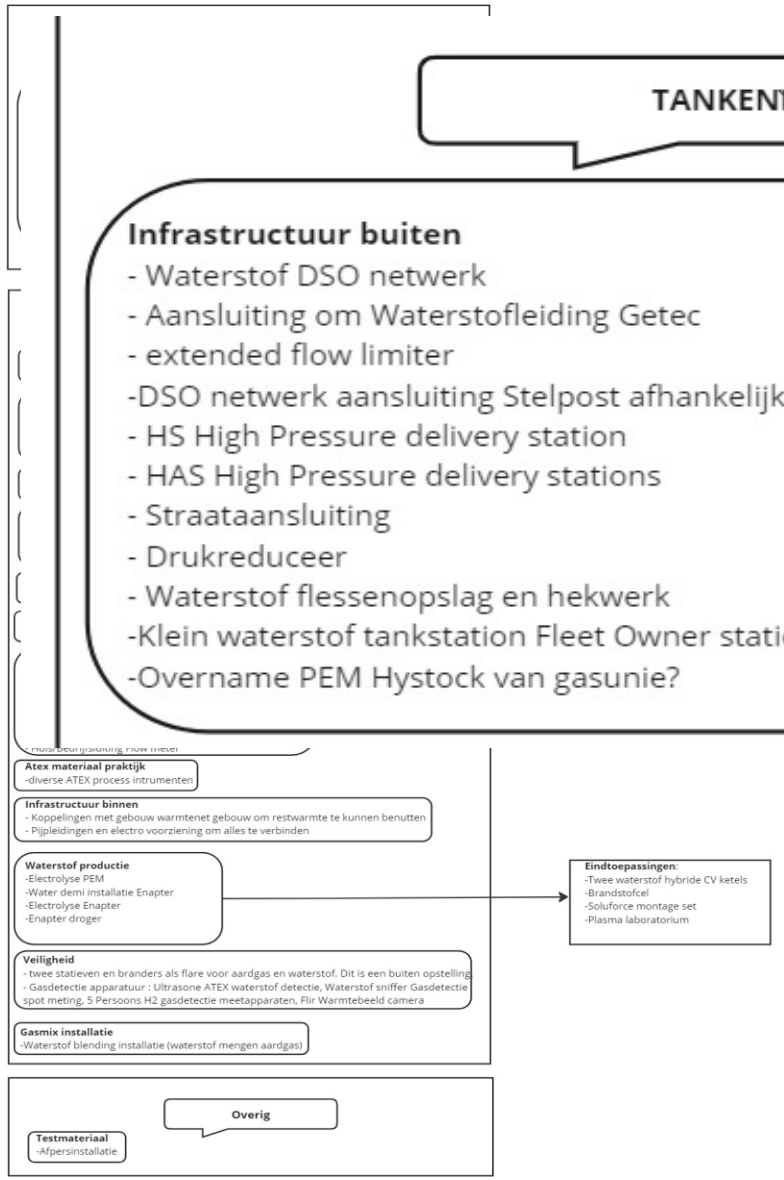
200 M^2 waterstoflabs binnen

100 M^2 waterstoflab buiten

Greenwise Campus Hydrogen Lab Analysis



Greenwise Campus – Hydrogenlab 1



Atex materiaal praktijk
-diverse ATEX process intrumenten

Infrastructuur binnen
- Koppelingen met gebouw warmtenet gebouw om restwarmte te kunnen benutten
- Pijpleidingen en electro voorziening om alles te verbinden

Waterstof productie
-Electrolyse PEM
-Water demi installatie Enapter
-Electrolyse Enapter
-Enapter droger

Veiligheid
- twee statieven en branders als flare voor aardgas en waterstof. Dit is een buiten opstelling
- Gasdetectie apparatuur : Ultrasone ATEX waterstof detectie, Waterstof sniffer Gasdetectie spot meting, 5 Persoons H2 gasdetectie meetapparaten, Flir Warmtebeeld camera

Gasmix installatie
-Waterstof blending installatie (waterstof mengen aardgas)

Greenwise Campus – Resato Academy



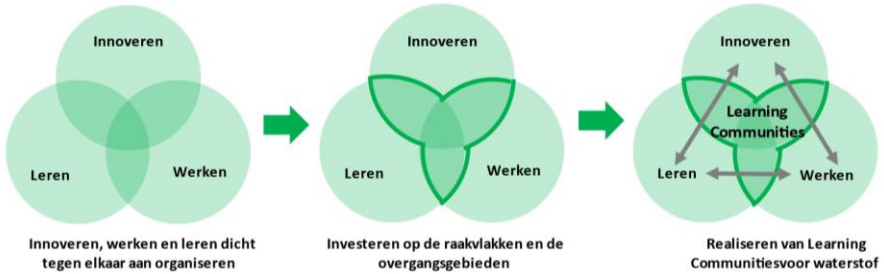




HYDROGREENN Ecosysteem

- Doel van het onderzoek is om Hydrogreenn ecosysteem in kaart te brengen voor o.a. gemeente Groningen, groenvermogenNL en Green WiseCampus.





HYDROGREENN

Also entH2usiastic?

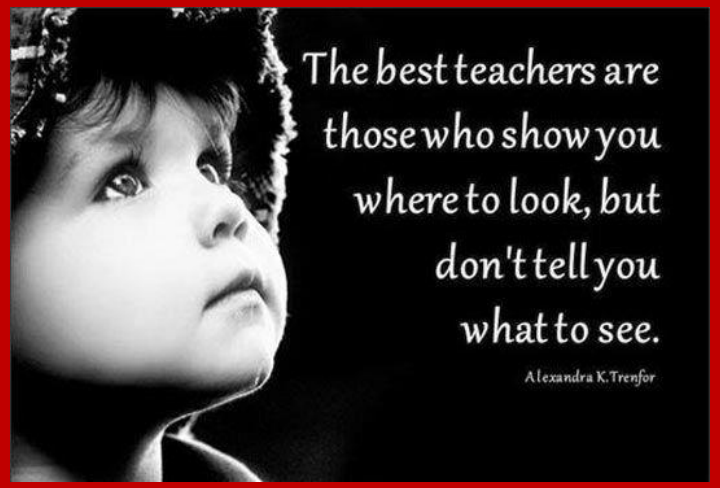


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