



understanding new energies

H₂ Lab - a Combined Training Platform

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leXsolar GmbH



About us

- Established in 2003 as a spin-off from the Technical university of Dresden/ Germany
- Worlddidac Award Winner
- One of the leaders in education in renewable energies
- Active in 60+ countries with over 50 partners

leXsolar areas of expertise



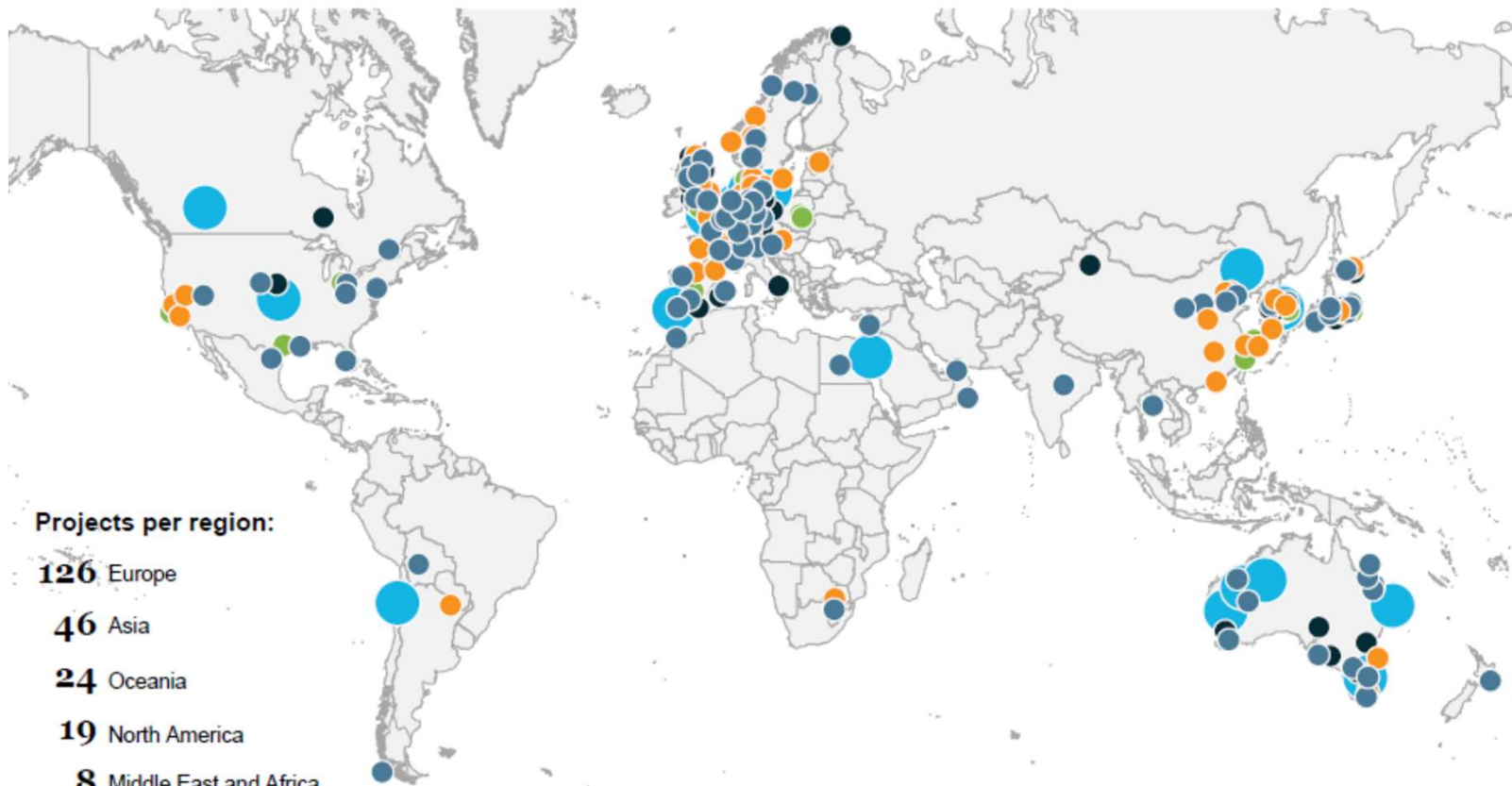
EU Environmental Strategy

- 55% reduction of emissions from cars by 2030
- Zero emissions from new cars by 2035
- Net zero emissions of greenhouse gases by 2050
- 40% new renewable energy target for 2030
- 160,000 additional green jobs could be created in the construction sector by 2030
- 35 million buildings could be renovated by 2030
- Economic growth decoupled from resource use
- 600 billion euro investments from NextGeneration EU Recovery Plan

The graphic features the text 'The European Green Deal' in a large, blue, sans-serif font. The text is overlaid on a background of a large green leaf with visible veins. Below the leaf, there is a blue, textured area that resembles water or a sky. The overall design is clean and modern, emphasizing environmental themes.

The European
Green Deal

Global Hydrogen Projects



Projects per region:

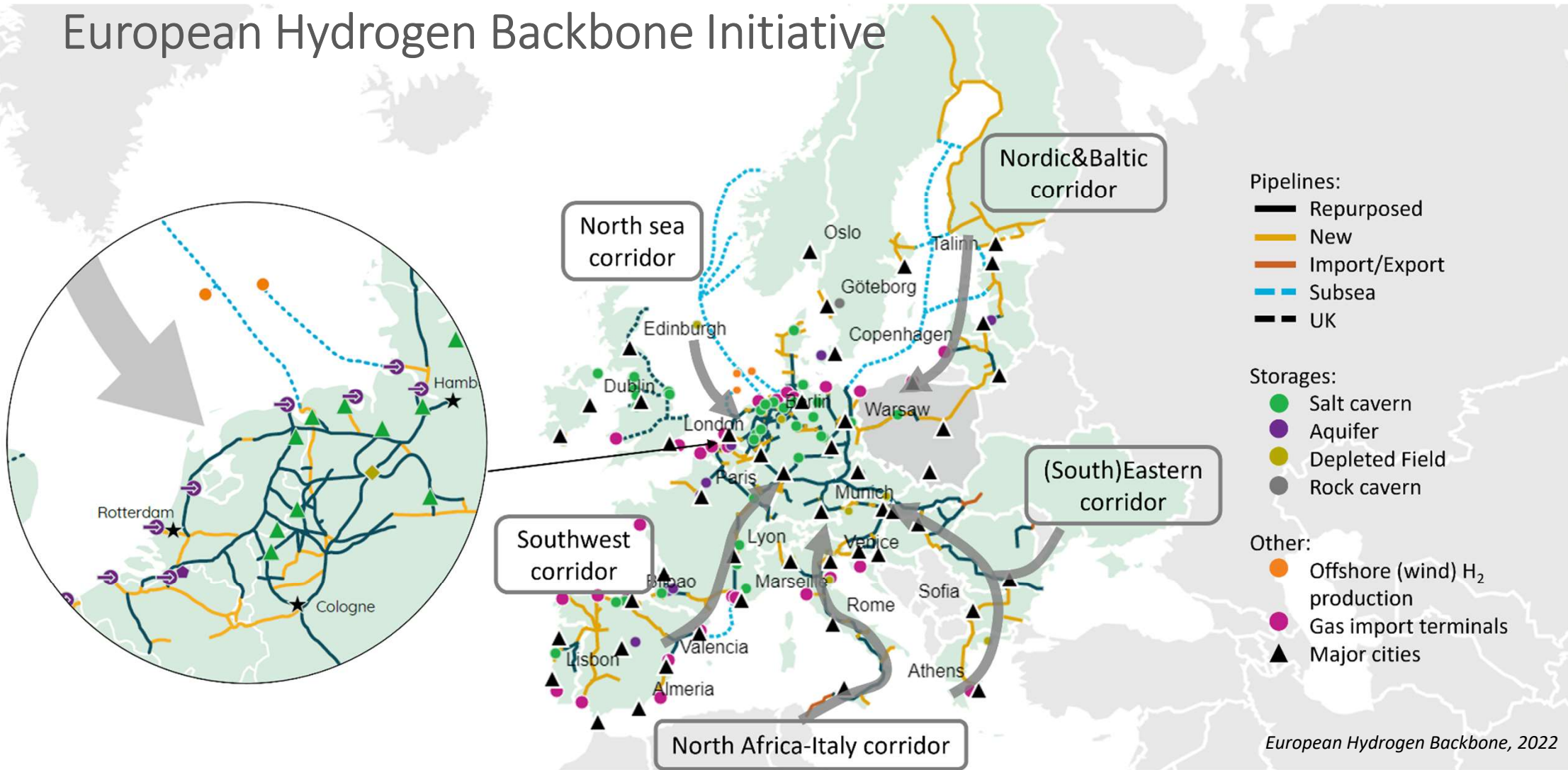
- 126** Europe
- 46** Asia
- 24** Oceania
- 19** North America
- 8** Middle East and Africa
- 5** Latin America

228 announced projects

Hydrogen Council, McKinsey & Company, Hydrogen Insights Report 2021

- 17**
Giga-scale production: renewable H₂ projects >1GW and low-carbon H₂ projects >200 kt p.a.
- 90**
Large-scale industrial usage: refinery, ammonia, power, methanol, steel, and industry feedstock
- 53**
Transport: trains, ships, trucks, cars and other hydrogen mobility applications
- 45**
Integrated H₂ economy: cross-industry, and projects with different types of end-uses
- 23**
Infrastructure projects: H₂ distribution, transportation, conversion, and storage

European Hydrogen Backbone Initiative

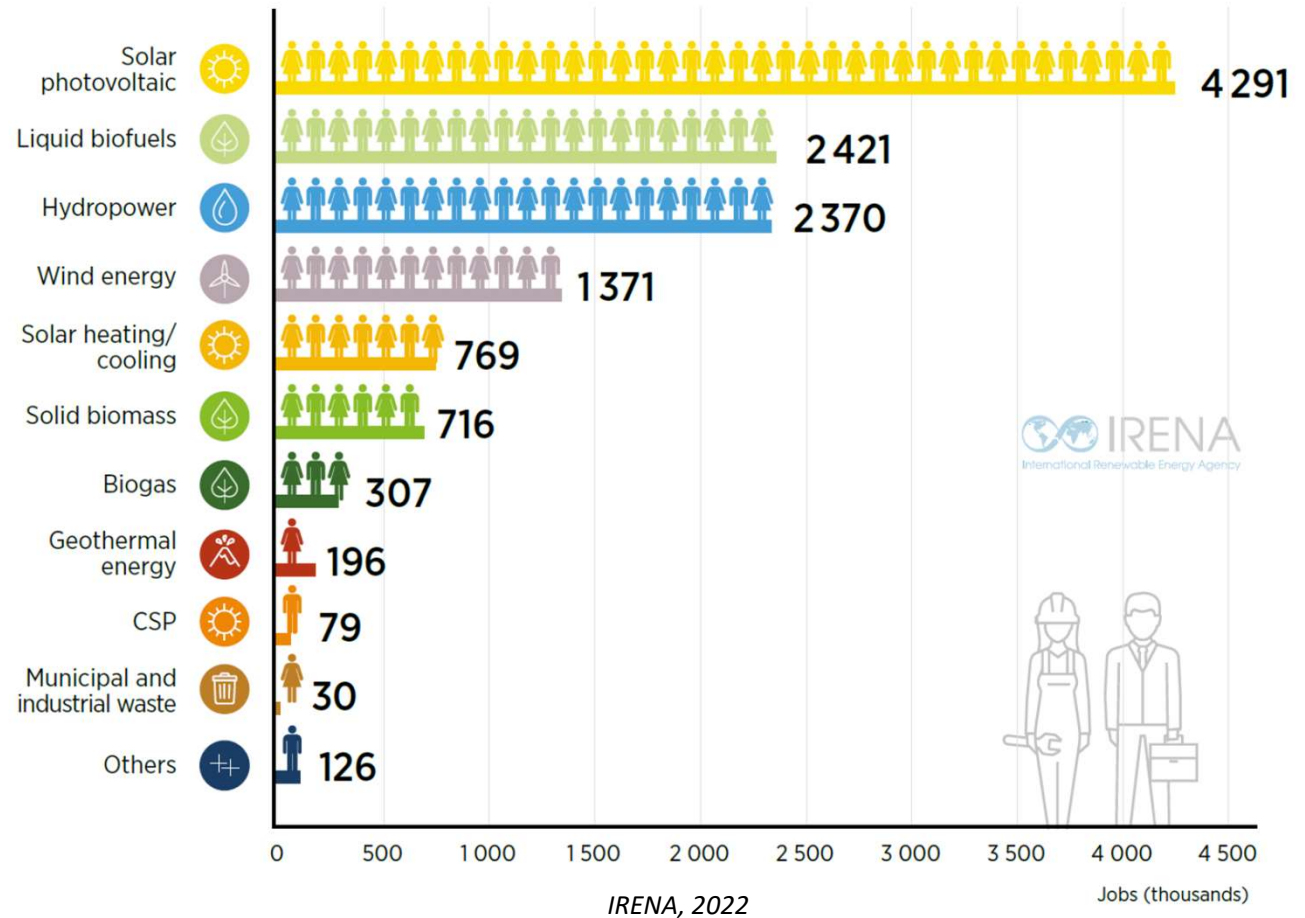


Jobs in Renewable Energy Sector

- Doubled since 2011
- Ca. 38 million are expected globally by 2030
- 134 million in the energy sector
- Asia accounted for 63% of total jobs in renewables globally



12.7
Million in 2021



IRENA
International Renewable Energy Agency



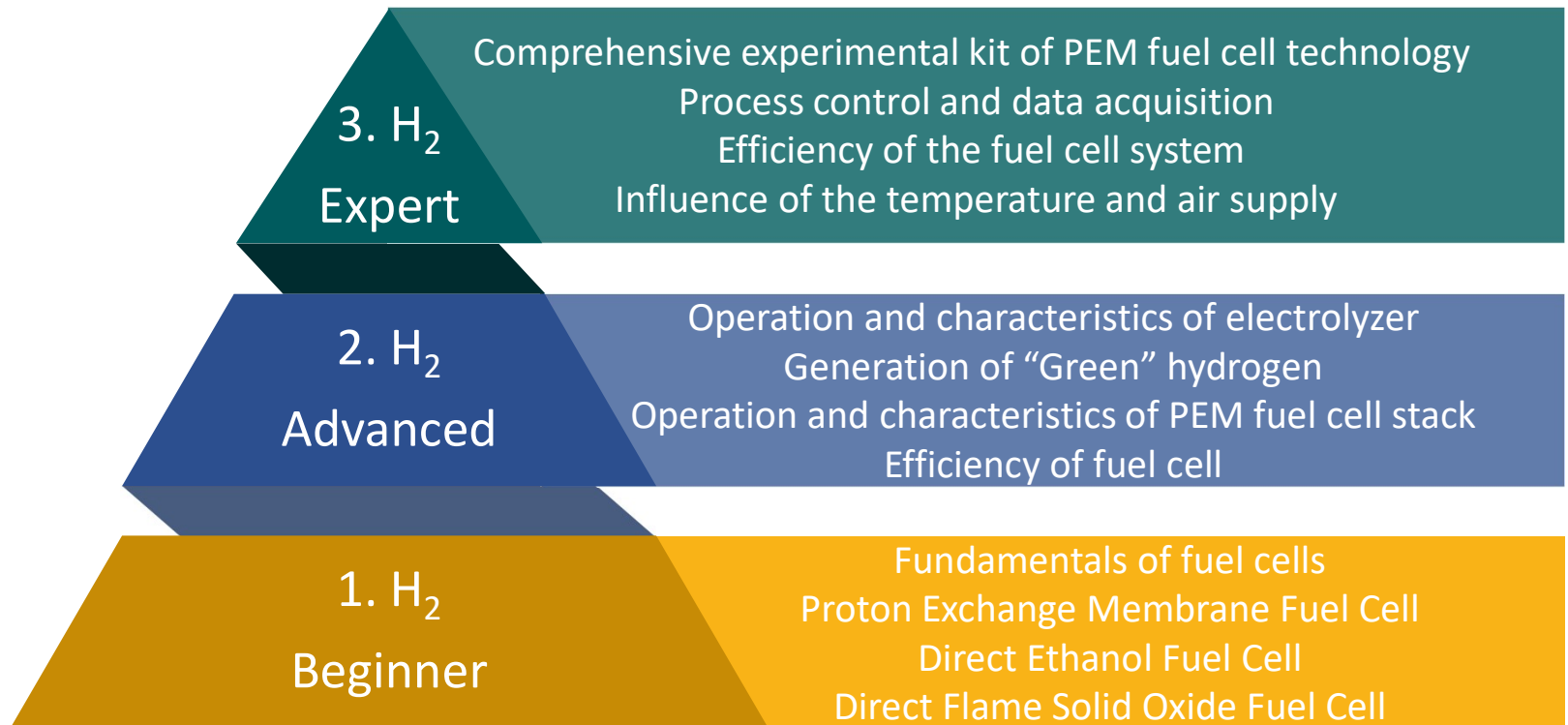


Module 0

- History of Fuel Cell Technologies
- H₂ Production
- H₂ Transport
- H₂ Storage
- H₂ Applications



leXsolar Experimental Kits





- Certification
- Blockchain credentials
- Issuer verification
- Certificate validation
- Skill pass

H₂ SPECIALIST - NUMBER 2657

H₂ SPECIALIST

CERTIFICATE

THIS TRAINING CERTIFICATE IS PRESENTED TO:

ERIK MÜLLER

Who has been successfully evaluated
on the experimental and theoretical course of leXsolar Specialist

H₂ Specialist

Powered by:

Michael Dietrich
leXsolar CEO
01 / 08 / 2022
Date completed

leXsolar
leXsolar GmbH

HYTEC
POWER Inc.
Certification center

Partner of: worlddidac, didacta, GREEN Solar Academy

H₂ Certificate Specialist

H₂ Microcertificate Expert
with 1223 leXsolar H₂ Expert for Technicians

H₂ Microcertificate Advanced
with 1222 leXsolar H₂ Professional for IVEI users

H₂ Microcertificate Elemental
with 1026 leXsolar H₂ Knowledge for Engineers

H₂ LAB Online learning course

1. History of Fuel Cell technologies
2. H₂ Production
3. H₂ Transport
4. H₂ Storage
5. H₂ Applications



H₂ Lab

Target group	TVET (Technical and Vocational Education and Training)
ISCED Level	5 - Short-cycle tertiary education
Age group	16 – 50+
Number of students	20-30 students per classroom
Students per equipment	6-12 Students can work simultaneously with experimental kits
Focus of lab-equipment	Green Energy Education for TVET
Subjects:	Renewable Energies, Environmental and Electrical Engineering, STEM, Chemical
Quality standard:	leXsolar is an official member of the Worlddidac Association and Didacta e.V. Germany

7 AFFORDABLE AND CLEAN ENERGY



4 QUALITY EDUCATION



13 CLIMATE ACTION



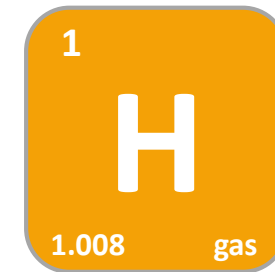
8 DECENT WORK AND ECONOMIC GROWTH





Module 0: Fundamentals of hydrogen technologies

- **Previous knowledge:**
 - School level STEM
- **Learning objectives:**
 - Hydrogen safety
 - Basics of hydrogen economy
 - Current and emerging methods for producing hydrogen
 - Applications of hydrogen and fuel cells
 - Options for storing and transporting hydrogen
- **Duration:**
 - 3 units
 - 4 – 8 hours (self-paced),
 - up to 16 hours (as a part of the guided lessons)





Module 0: Fundamentals of hydrogen technologies

Production of Hydrogen

Colors of hydrogen
Hydrogen emits just water when burned - but creating it can be very carbon intensive. Various ways to lessen this impact have been developed one is the assigning of colors to the different types:

GREY HYDROGEN
BLUE HYDROGEN
GREEN HYDROGEN

H2- Basics and production of hydrogen

Transport and Storage

Transporing hydrogen via road.
Today, hydrogen normally is transported from the point of production to the point of use via pipeline and over the road in cryogenic liquid tanker trucks or gaseous tube trailers. Due to the achievable transport volume road transport is used primarily for smaller quantities and local distribution.

H2- Basics and production of hydrogen

Application

There are several types of fuel cells, that vary based on their operating temperature, materials, and design. PEMFC is currently the most researched and tested type in industry and academia, while AFC, PAFC, and MCFC have declined in importance due to technical issues during field tests and a lack of confidence in cost reduction.

H2- Basics and production of hydrogen

- Hydrocarbon Reforming
 - Steam Reforming
 - Partial Oxidation
- Hydrocarbon Pyrolysis
- Biological Processes
- Electrolysis
 - Alcaline
 - Solid Oxide Electrolyser Cell
 - Proton Exchange Membrane
- Other methods

- Chemical-based storage
 - Adsorbent
 - Liquid organic
 - Hydride
- Physical-based storage:
 - Liquid storage
 - Gas storage
- Hydrogen transport

- Hydrogen as energy carrier
- Hydrogen as fuel
 - Portable
 - Stationary
 - Mobility
- Hydrogen in fuel cells
 - Proton Exchange Membrane
 - Alcaline
 - Phosphoric Acid
 - Molten Carbonate
 - Solid Oxide
 - Direct Alcohol



Module 1: H₂ Beginner

Previous knowledge:

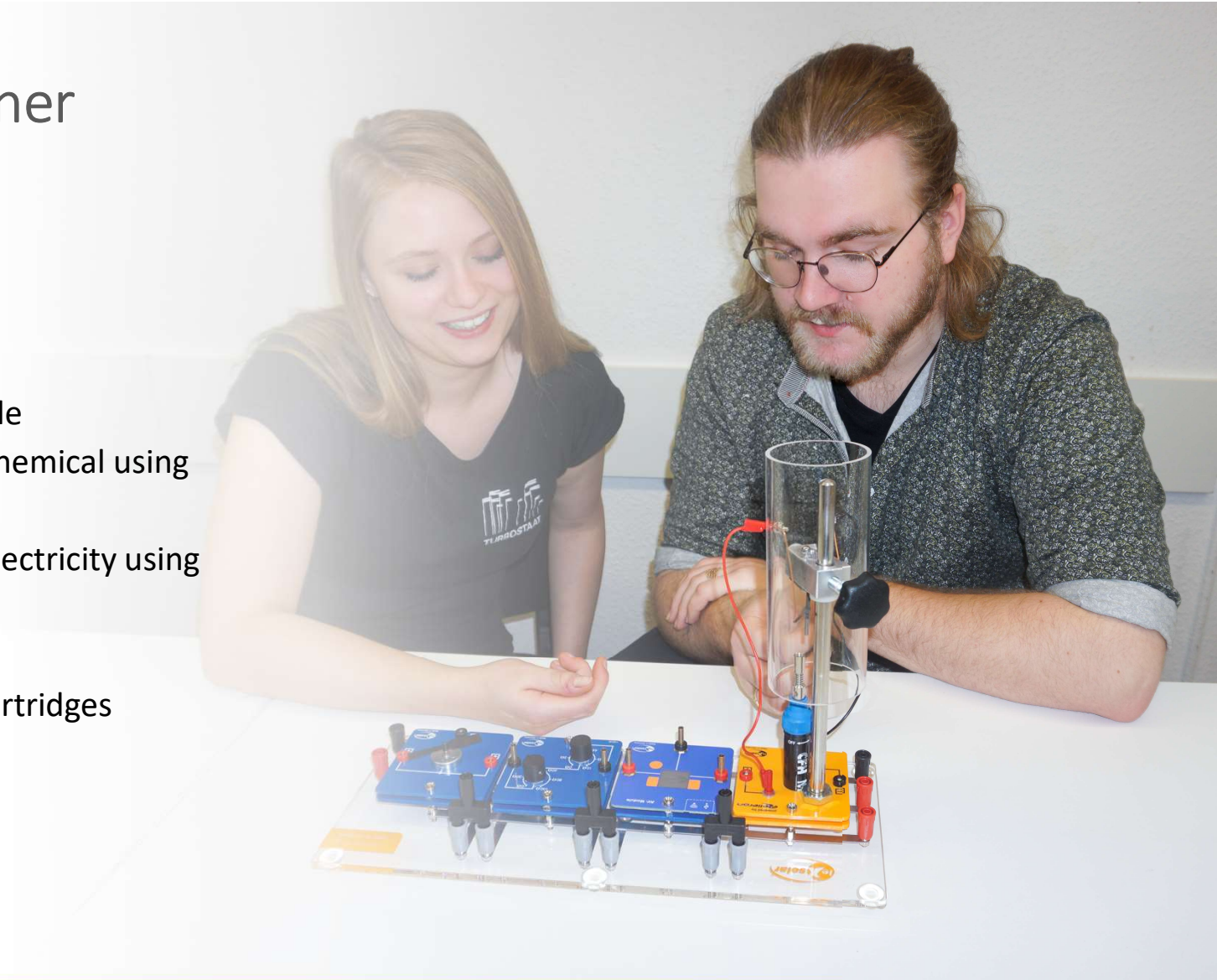
- Not required

Learning objectives:

- Basics of a solar-hydrogen energy cycle
- Conversion of electrical energy into chemical using electrolyser
- Conversion of chemical energy into electricity using fuel cells
- Types of fuel cell (PEM, EtOH, SOFC)
- Hydrogen storage in metal-hydride cartridges

Duration:

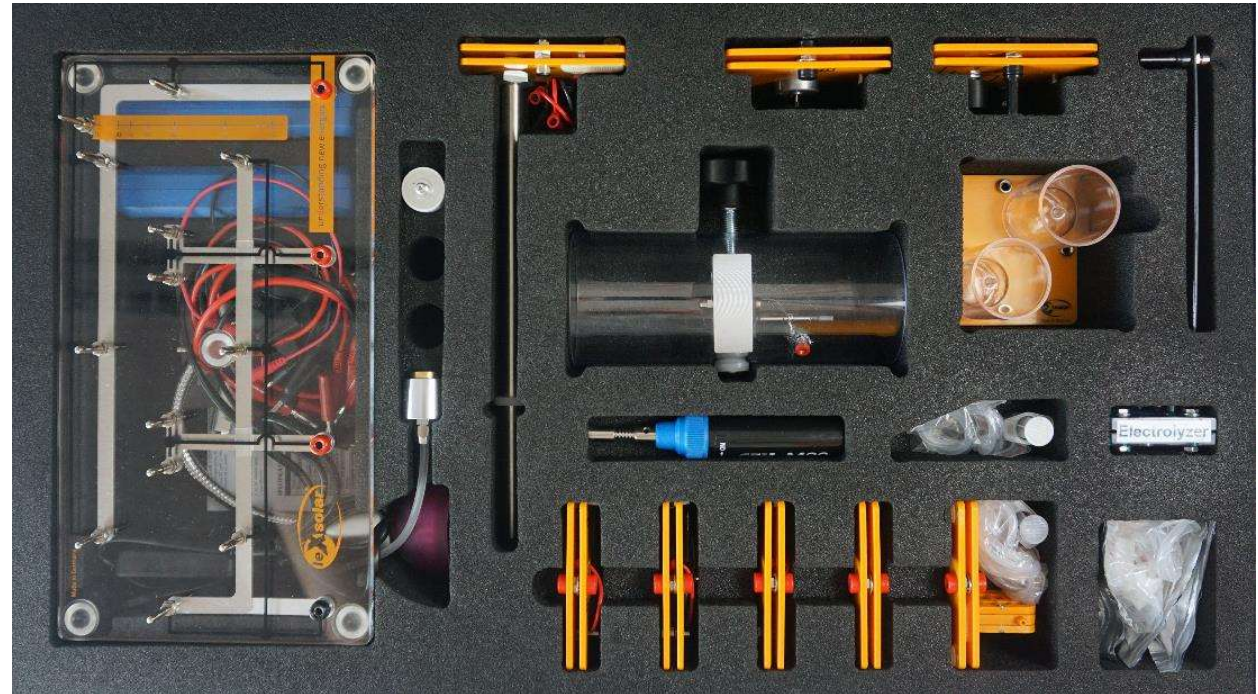
- 4 main units; 8 - 12 hours





H₂ Beginner: Components

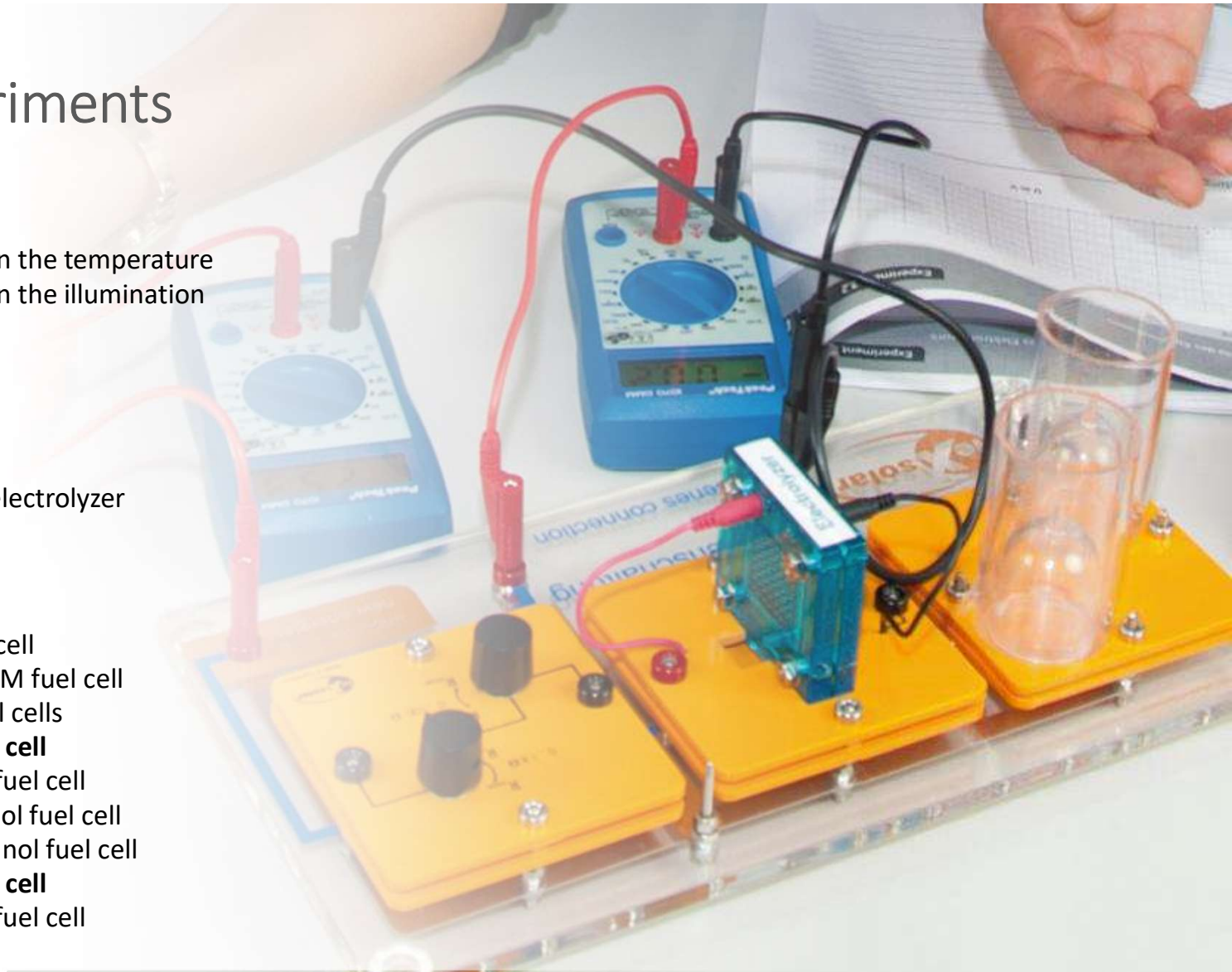
- Base unit
- Potentiometer module
- Motor module
- Solar module 2.5 V, 420 mA
- H₂ Storage
- Gas storage module
- 3x PEM-Fuel Cell Module
- Electrolyzer module 2.0
- Ethanol fuel cell
- SOFC fuel cell
- Fuel cell stand
- Gas burner
- Lamp with table clamp
- 2x Digital multimeter
- 2x Test lead black 25 cm
- 2x Test lead red 25 cm
- Test lead black 50 cm
- Test lead red 50 cm
- Valve for H₂ Storage
- Silicone hose 4 mm (o.d.)





H₂ Beginner: Experiments

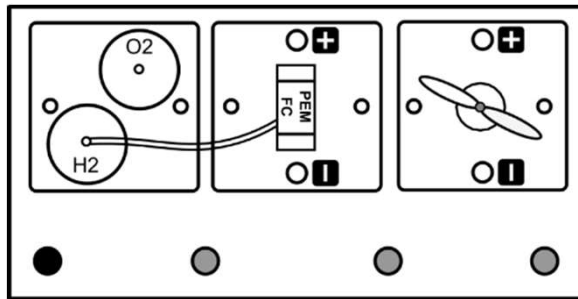
- **Basic experiments:**
 - I-V characteristics of the solar cell
 - Dependence of the solar cell power on the temperature
 - Dependence of the solar cell power on the illumination intensity
- **Experiments with electrolyzer:**
 - Generation of “green” hydrogen
 - I-V characteristics of the electrolyzer
 - Faraday and energy efficiency of the electrolyzer
- **Experiments with fuel cell:**
 - **Properties of a PEM fuel cell**
 - I-V characteristic curve of a PEM fuel cell
 - Faraday- and energy efficiency of a PEM fuel cell
 - Series and parallel circuits of PEM fuel cells
 - **Working principles of an ethanol fuel cell**
 - I-V characteristic curve of an ethanol fuel cell
 - Temperature dependence of an ethanol fuel cell
 - Concentration dependence of an ethanol fuel cell
 - **Working principles of solid oxide fuel cell**
 - I-V characteristic curve of an ethanol fuel cell



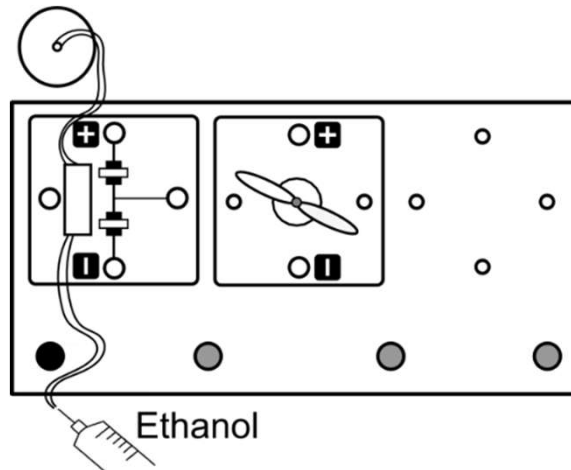


H₂ Beginner: Working principle of the fuel cells

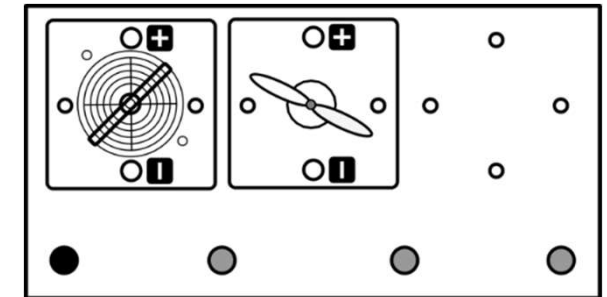
Investigate and compare the working principle of PEM, EtOH, and SOFC fuel cells



- Base unit
- Electrolyser or H₂ storage
- PEM fuel cell
- Motor module



- Base unit
- Ethanol fuel cell
- Ethanol
- Syringe
- Motor module



- Base unit
- SOFC fuel cell
- Gas burner
- Motor module



Module 2: H₂ Advanced

Previous knowledge:

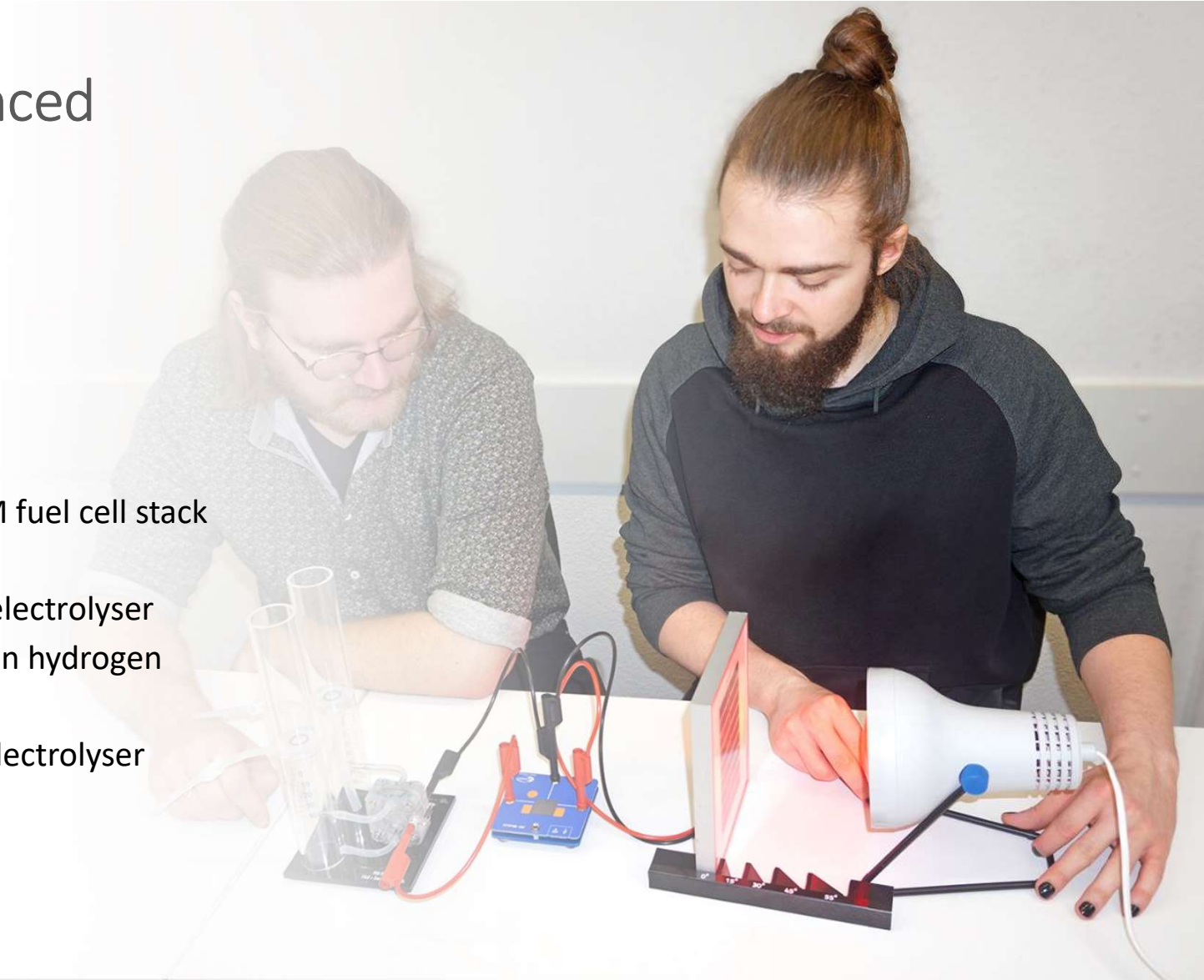
- Fundamentals of electrolysis
- Working principle of PEM fuel cells

Learning objectives:

- Basic properties of the solar cell
- Operation and properties of the PEM fuel cell stack (1-5 cells)
- Operation and characteristics of an electrolyser
- Solar-hydrogen energy cycle for green hydrogen generation
- Efficiency of the fuel cell stack and electrolyser

Duration:

- 3 main units; 8 - 12 hours





Module 2: H₂ Advanced

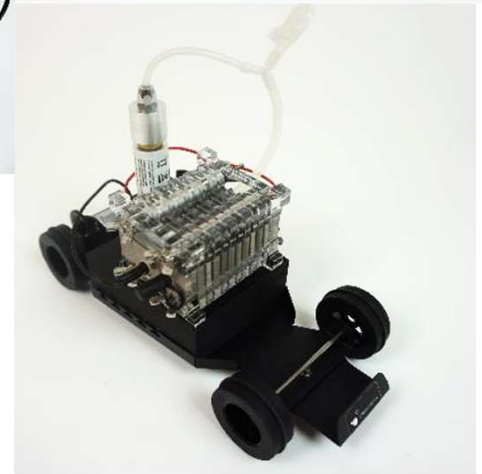
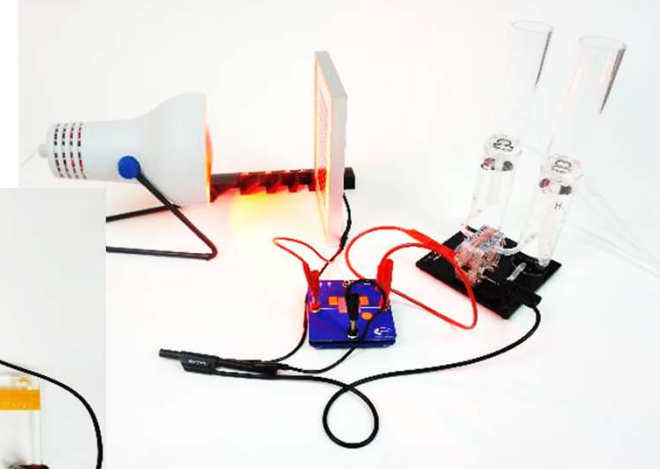
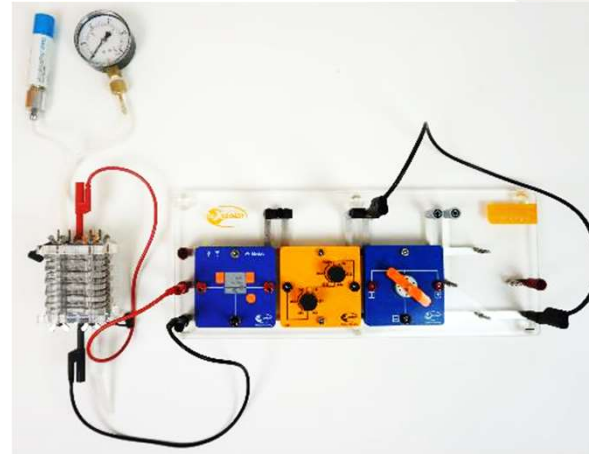
- Double cell electrolyser
- Fuel cell stack (1-5 cells)
- Model car
- Base unit
- Solar cell module 5,2 V with stand
- Infrared lamp
- Potentiometer
- AV module
- Power module
- Blower fan
- H₂ storage (metal hydride, 30 bar, 10 l)
- One-step pressure regulator
- Adapter 2 mm/4 mm
- Short circuit plugs
- Safety cables (4 mm), adapters
- Aluminum case





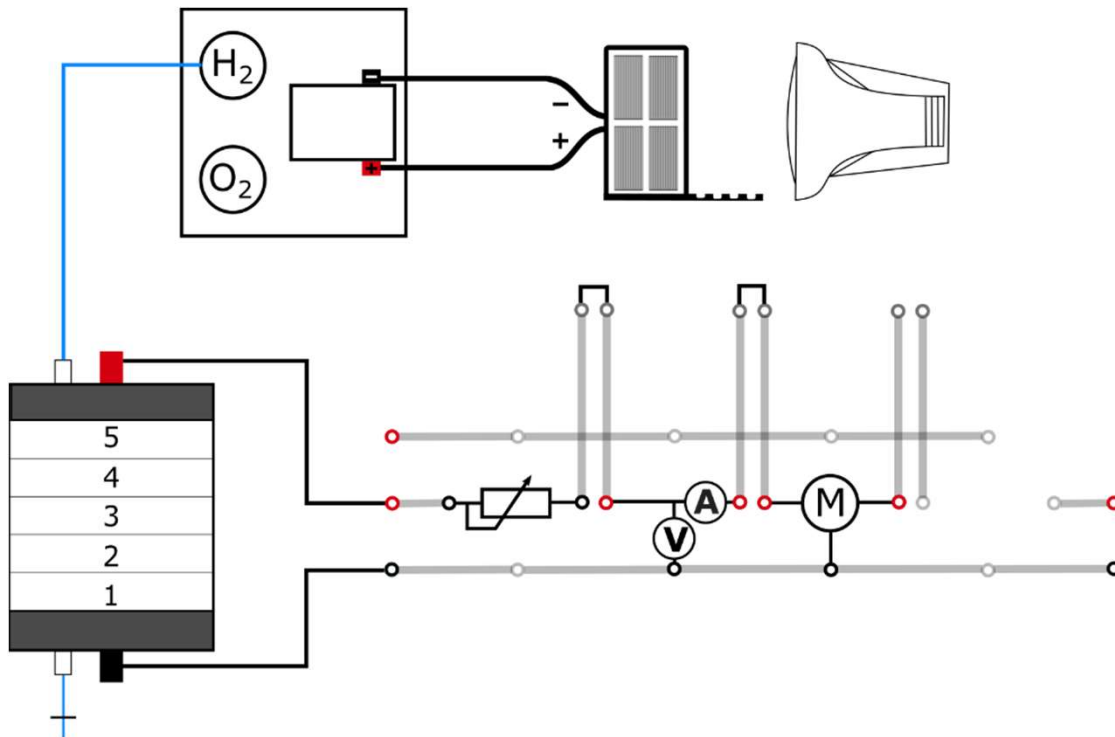
H₂ Advanced: Experiments

- **Basic experiments:**
 - I-V characteristics of the solar cell
 - Dependence of the solar cell power on the temperature
 - Dependence of the solar cell power on the illumination intensity
- **Experiments with electrolyzer:**
 - Properties of the electrolyzer:
 - I-V characteristics of the electrolyzer
 - **Solar-powered generation of hydrogen**
 - Faraday and energy efficiency of the electrolyzer
- **Experiments with fuel cell:**
 - **Operation of the consumer with the 5-cell stack**
 - Examination of the single cell compared to the fuel cell stack
 - Operation of the fuel cell stack with and without fan
 - Faraday and energy efficiency of the fuel cell stack
 - Operation of the model car with a fuel cell stack
 - Hydrogen consumption of the fuel cell



H₂ Advanced: Green Hydrogen Production

Direct utilization of produced “green” hydrogen in PEM fuel cell stack



Equipment:

- Base unit
- Solar module + base for solar panel
- Lamp
- AV-Module
- Potentiometer module Electrolyser
- Fuel cell stack
- Cables and adapters

Optional:

- Power module, 4V (for “brown” hydrogen generation)



Module 3: H₂ Expert

Previous knowledge:

- Working principle of the PEM fuel cell
- Efficiency of the PEM fuel cell

Learning objectives:

- PEM fuel cell stack
- Process control and efficiency of the fuel cell system
- Operating modes of the fuel cell system
- Recognizing and eliminating errors
- Hydrogen consumption

Duration:

- 1 main unit; 6-10 hours





H₂ Expert: Components

Fuel cell stack:

- Type: Proton Exchange Membrane (PEM)
- Nominal power: 20 W (7.6 V @ 2.6 A)
- Open circuit voltage: 12 V
- Start-up time: ≤ 30 s (25 °C)
- Maximal stack temperature: 55 °C
- H₂ pressure: 0.4 - 0.6 bar

Controller:

- Control unit for the fuel cell
- Data acquisition (cell temperature, H₂ pressure, voltage, current, power)
- Integrated webserver with control dashboard and data logger
- Error management
- Export of measured data as .csv

Electronic load:

- Input voltage: 1 – 30 V
- Discharge current: 0 - 5 A, adjustable in 0.01 A
- Power supply: 12 V
- Maximum power: 35 W





H₂ Expert: Experiments

1. Set up and operation of the fuel cell system
2. I-V characteristic curve of the fuel cell stack
3. Efficiency of the fuel cell stack
4. Parameters influencing the characteristic curve
5. Hydrogen consumption of the fuel cell stack
6. Efficiency of a fuel cell system



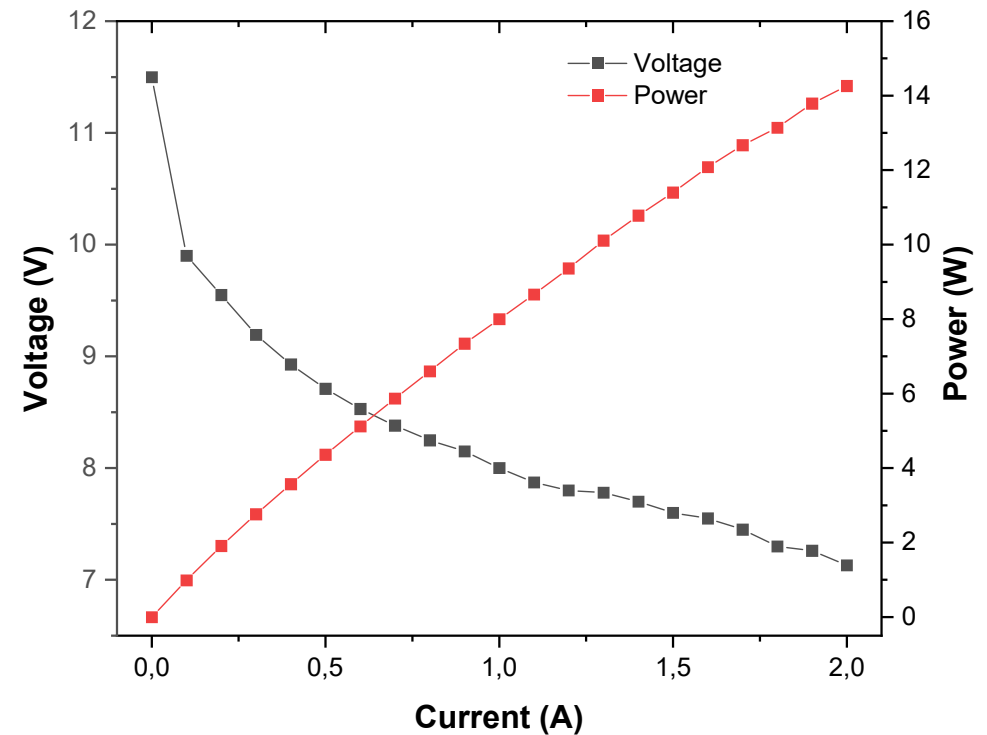
H₂ Expert: I-V Characteristics of the Fuel Cell Stack

Determine the voltage-current characteristics of a fuel cell stack



Equipment:

- Fuel cell stack
- Fuel cell controller (<http://webapp.fuelcell.de>)
- Fuel cell stand
- H₂ storage
- Load connection cable

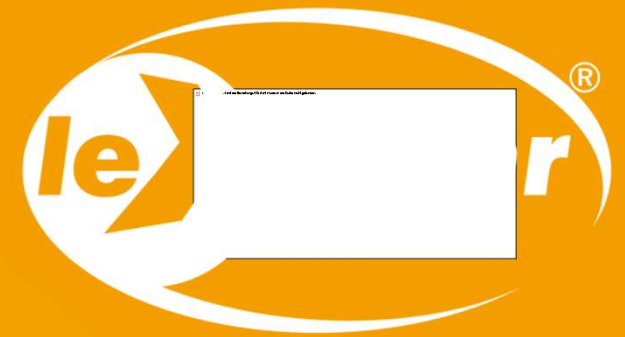




H₂ Lab: Safety

- Small volume of produced hydrogen and oxygen (max. 80 ml)
- Relatively low-pressure metal hydride hydrogen storage (30 Bar, max. 10 L)
- Hydrogen generator for recharging metal-hydride cartridges
- Direct alcohol fuel cell with non-toxic ethanol as a fuel
- Solid oxide fuel cell does not require an external heater
- Can be used in almost every laboratory and classroom with adequate ventilation





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Summary



Advantages:

- Sustainable development
- Non-toxic energy transfer operation
- Energy security
- Universality
- Global environment issue
- Technological innovation

Barriers:

- Safety
- Liquid hydrogen storage
- Increased production cost
- Increased conversion cost
- Viability/cost – low ratio
- Logistics require expensive investments