understanding new energies

H_2 Lab - a Combined Training Platform

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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

References


Goldwind


HYPOS
macht Schule


EnBW


berlin


DLR


MITNETZ
GAS


e·on


ETH zürich


B N W
Bildungswerk der
Niedersächsischen Wirtschaft
gemeinnützige GmbH

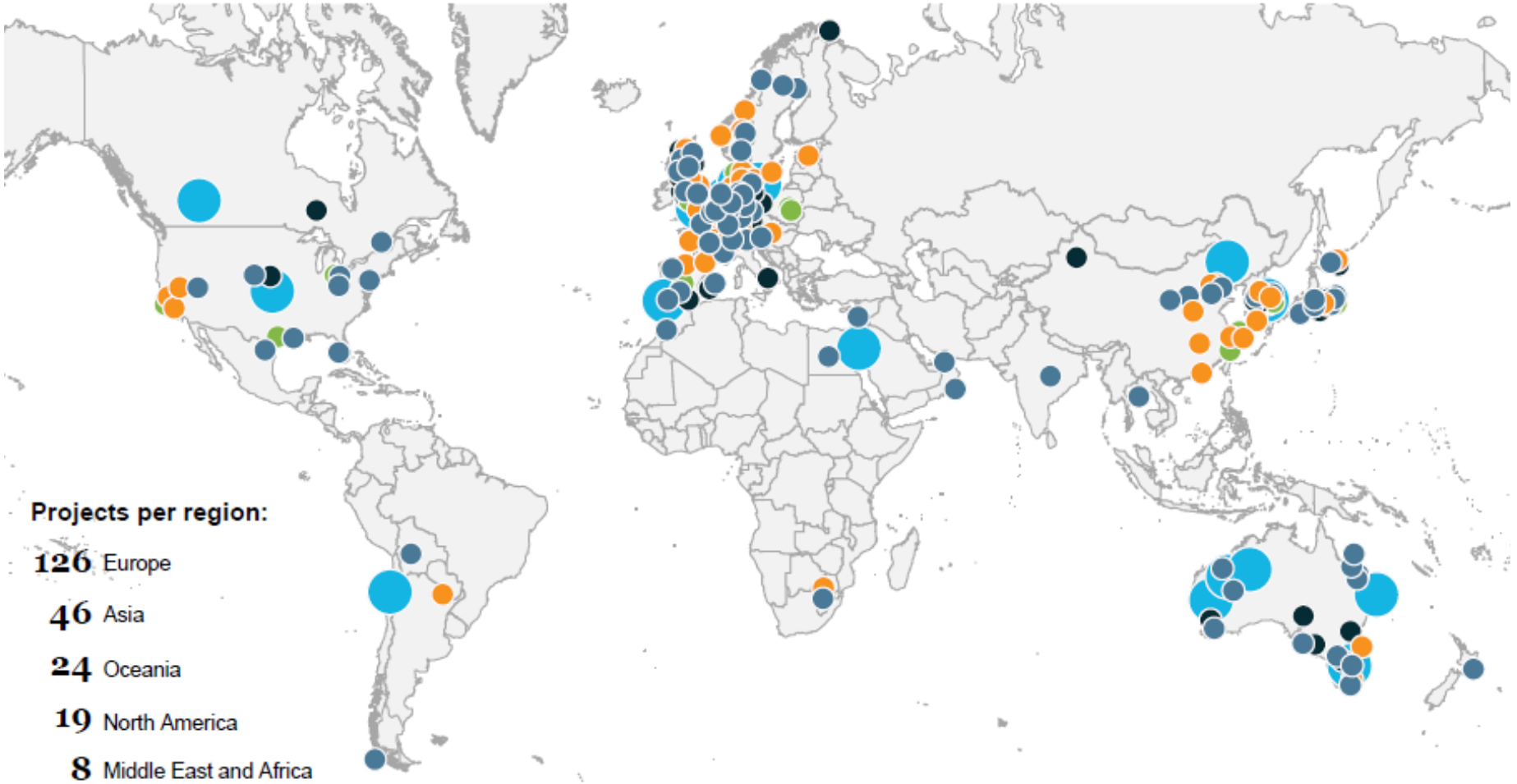

RheinEnergie


Enervie
Südwestfalen Energie und Wasser AG


EWEnetz


Fraunhofer
IMWS

Global Hydrogen Projects



Projects per region:

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

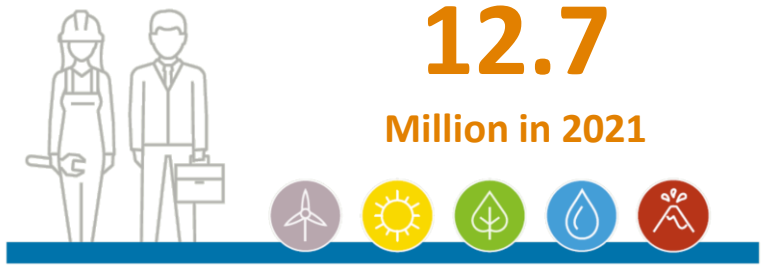
228 announced projects

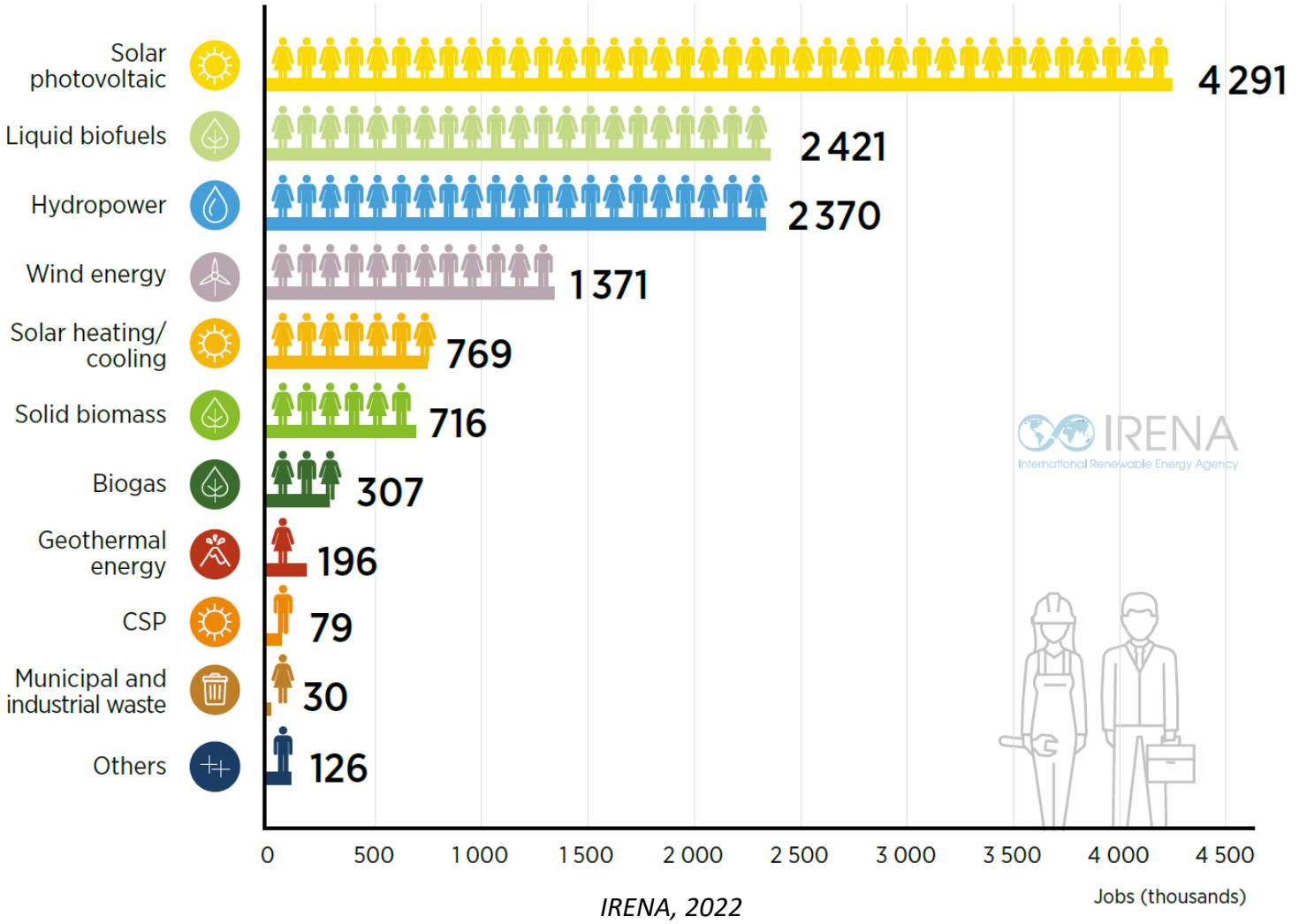
- **17** **Giga-scale production:** renewable H_2 projects >1GW and low-carbon H_2 projects >200 kt p.a.
- **90** **Large-scale industrial usage:** refinery, ammonia, power, methanol, steel, and industry feedstock
- **53** **Transport:** trains, ships, trucks, cars and other hydrogen mobility applications
- **45** **Integrated H_2 economy:** cross-industry, and projects with different types of end-uses
- **23** **Infrastructure projects:** H_2 distribution, transportation, conversion, and storage

Hydrogen Council, McKinsey & Company, Hydrogen Insights Report 2021

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





IRENA, 2022

leXsolar H_2 Lab

Module 0

- History of Fuel Cell Technologies
- H_2 Production
- H_2 Transport
- H_2 Storage
- H_2 Applications

leXsolar Experimental Kits

3. H_2 Expert
Comprehensive experimental kit of PEM fuel cell technology
Process control and data acquisition
Efficiency of the fuel cell system
Influence of the temperature and air supply

2. H_2 Advanced
Operation and characteristics of electrolyzer
Generation of “Green” hydrogen
Operation and characteristics of PEM fuel cell stack
Efficiency of fuel cell

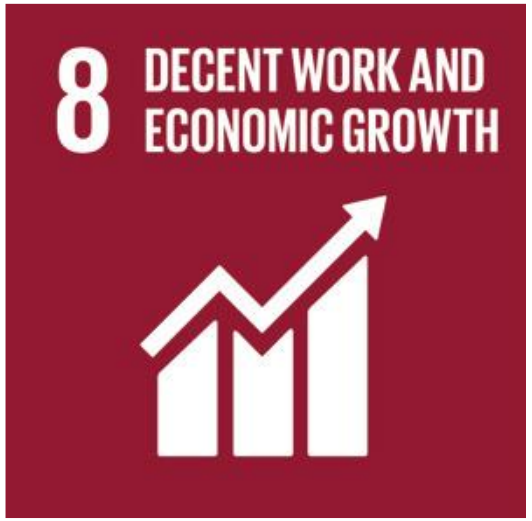
1. H_2 Beginner
Fundamentals of fuel cells
Proton Exchange Membrane Fuel Cell
Direct Ethanol Fuel Cell
Direct Flame Solid Oxide Fuel Cell

H_2 Lab

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

H_2 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



Module 0: Fundamentals of hydrogen technologies

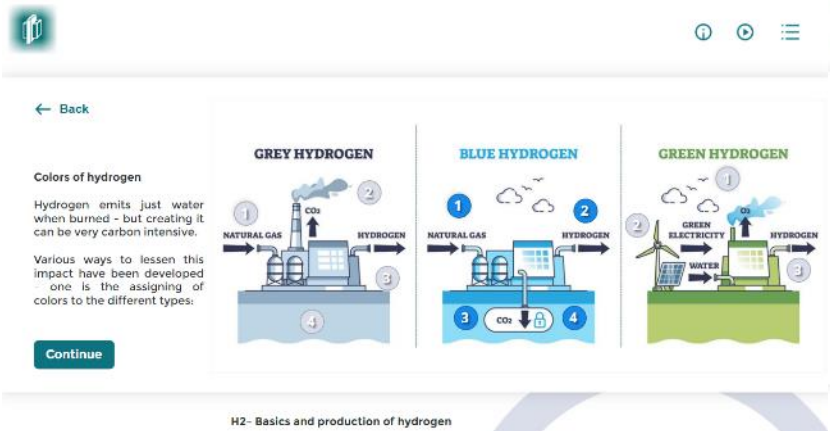
- **Previous knowledge:**
  - School level STEM

- **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)

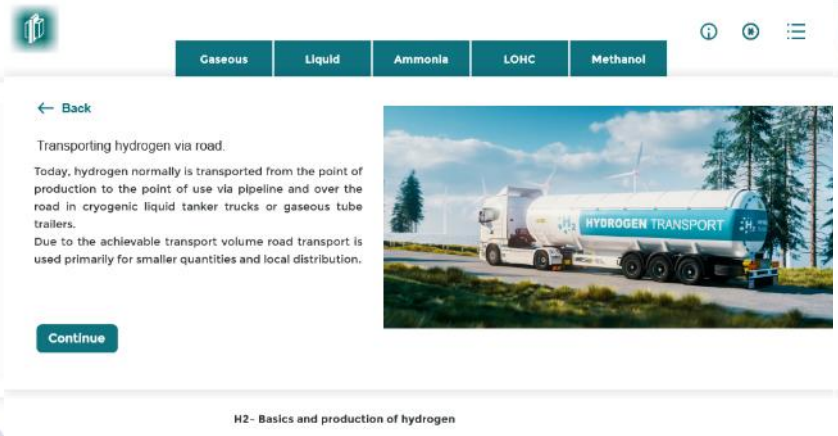
Module 0: Fundamentals of hydrogen technologies

Production of Hydrogen



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

Transport and Storage



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

Application

- 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: H_2 Beginner

Previous knowledge:

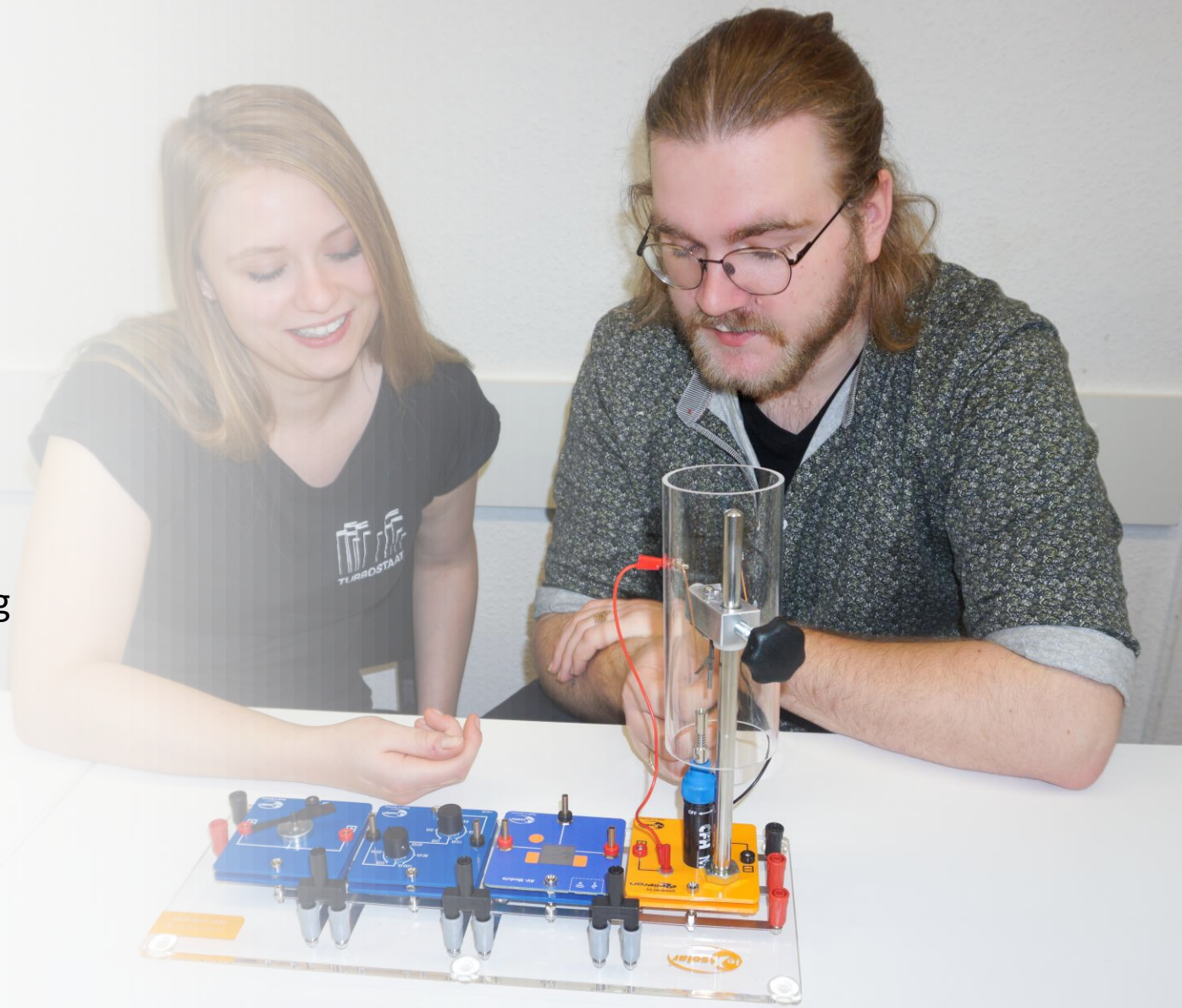
- Not required

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

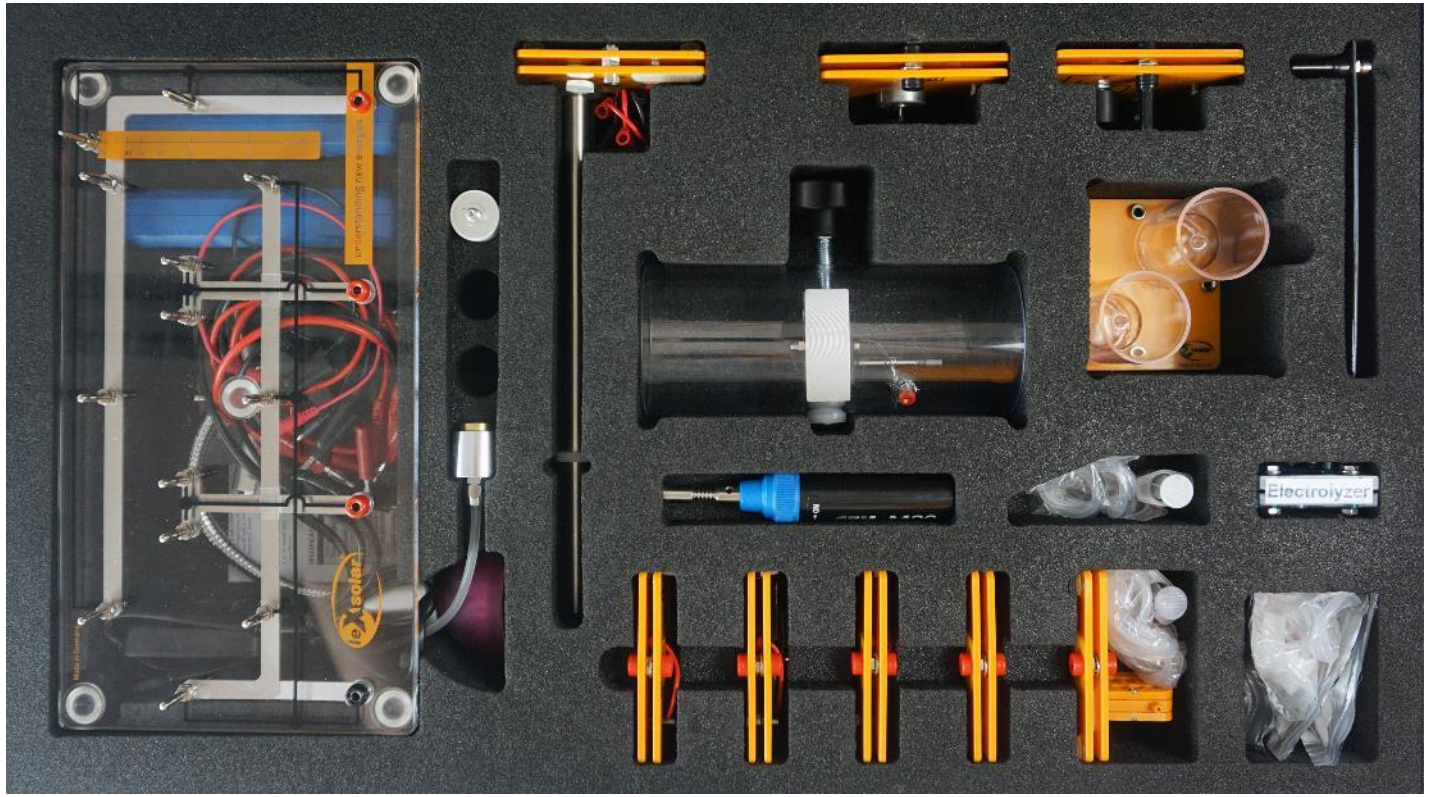
Duration:

- 4 main units; 8 - 12 hours



H_2 Beginner: Components

- Base unit
- Potentiometer module
- Motor module
- Solar module 2.5 V, 420 mA
- H_2 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 H_2 Storage
- Silicone hose 4 mm (o.d.)

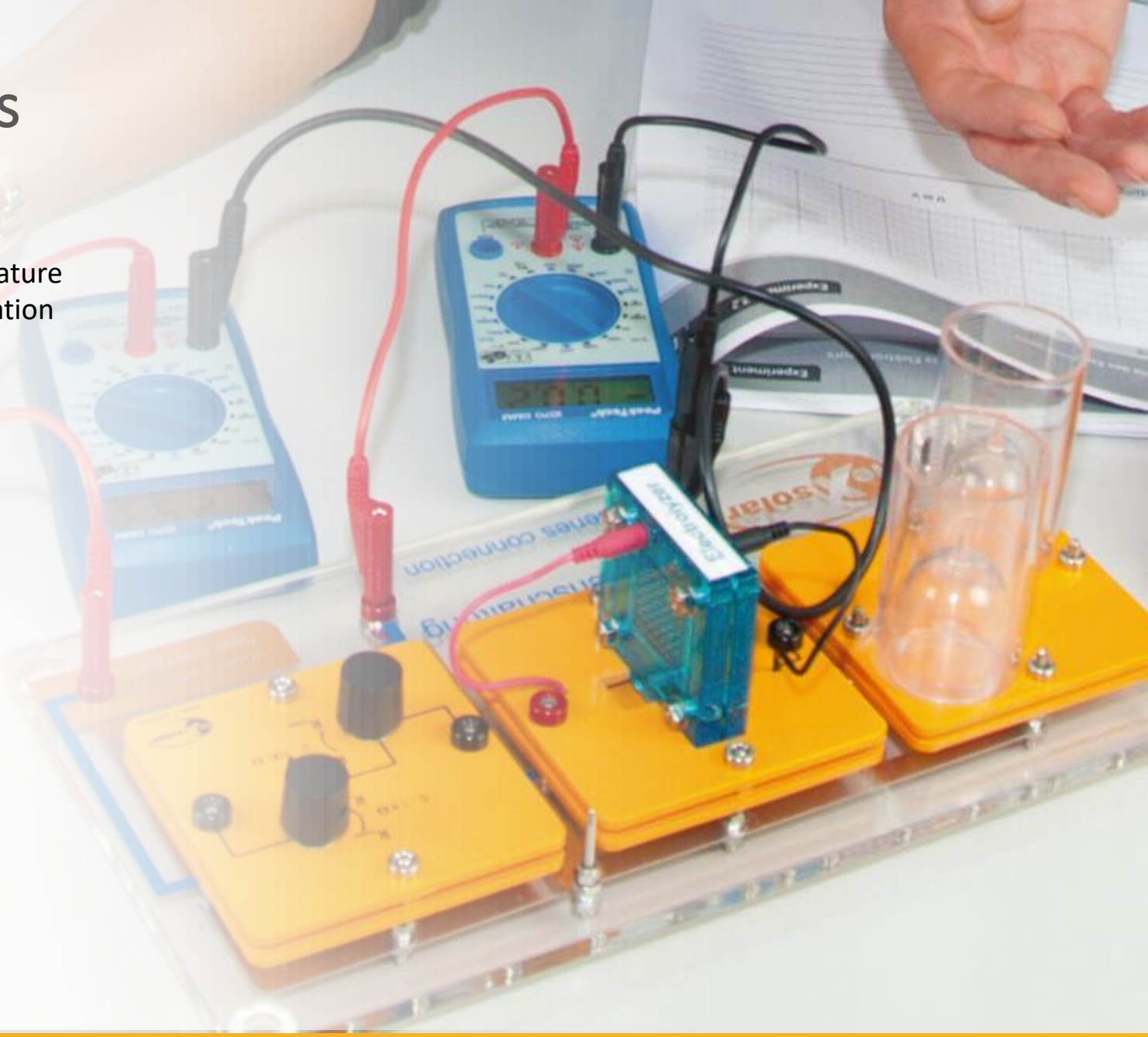


H_2 Beginner: Experiments

- **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

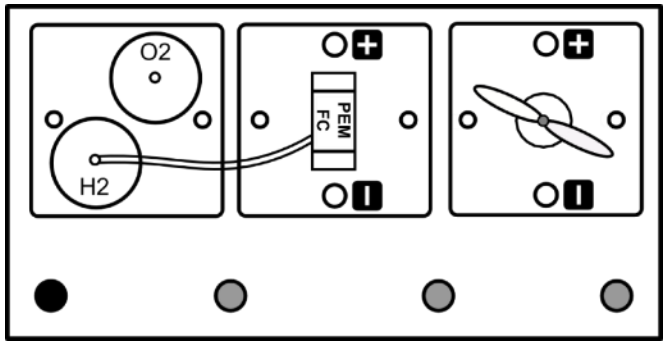
- **Experiments with electrolyzer:**
  - Generation of “green” hydrogen
  - I-V characteristics of the electrolyzer
  - Faraday and energy efficiency of the electrolyzer

- **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

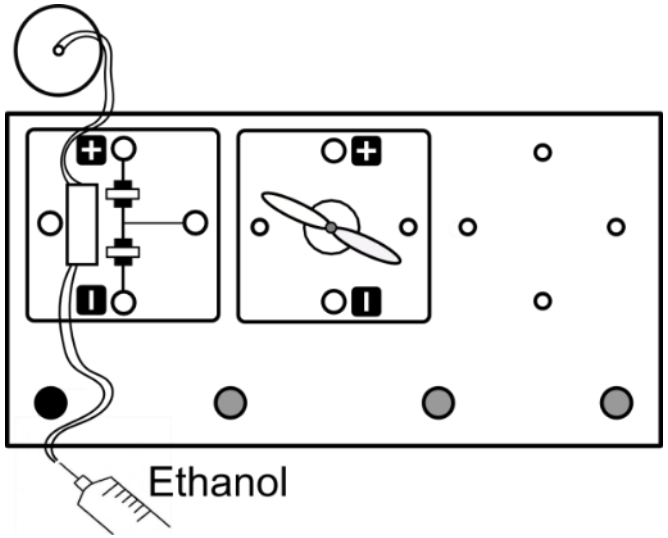


H_2 Beginner: Working principle of the fuel cells

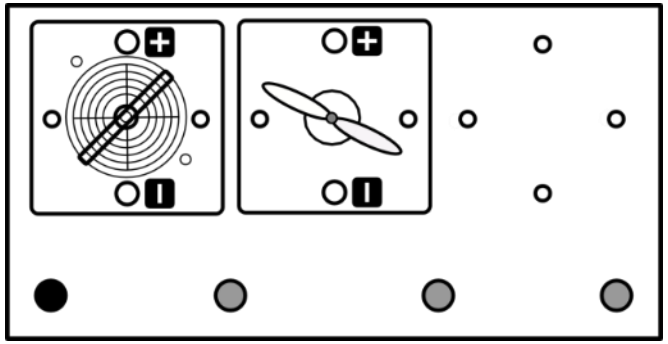
Investigate and compare the working principle of PEM, EtOH, and SOFC fuel cells



- Base unit
- Electrolyser or H_2 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: H_2 Advanced

Previous knowledge:

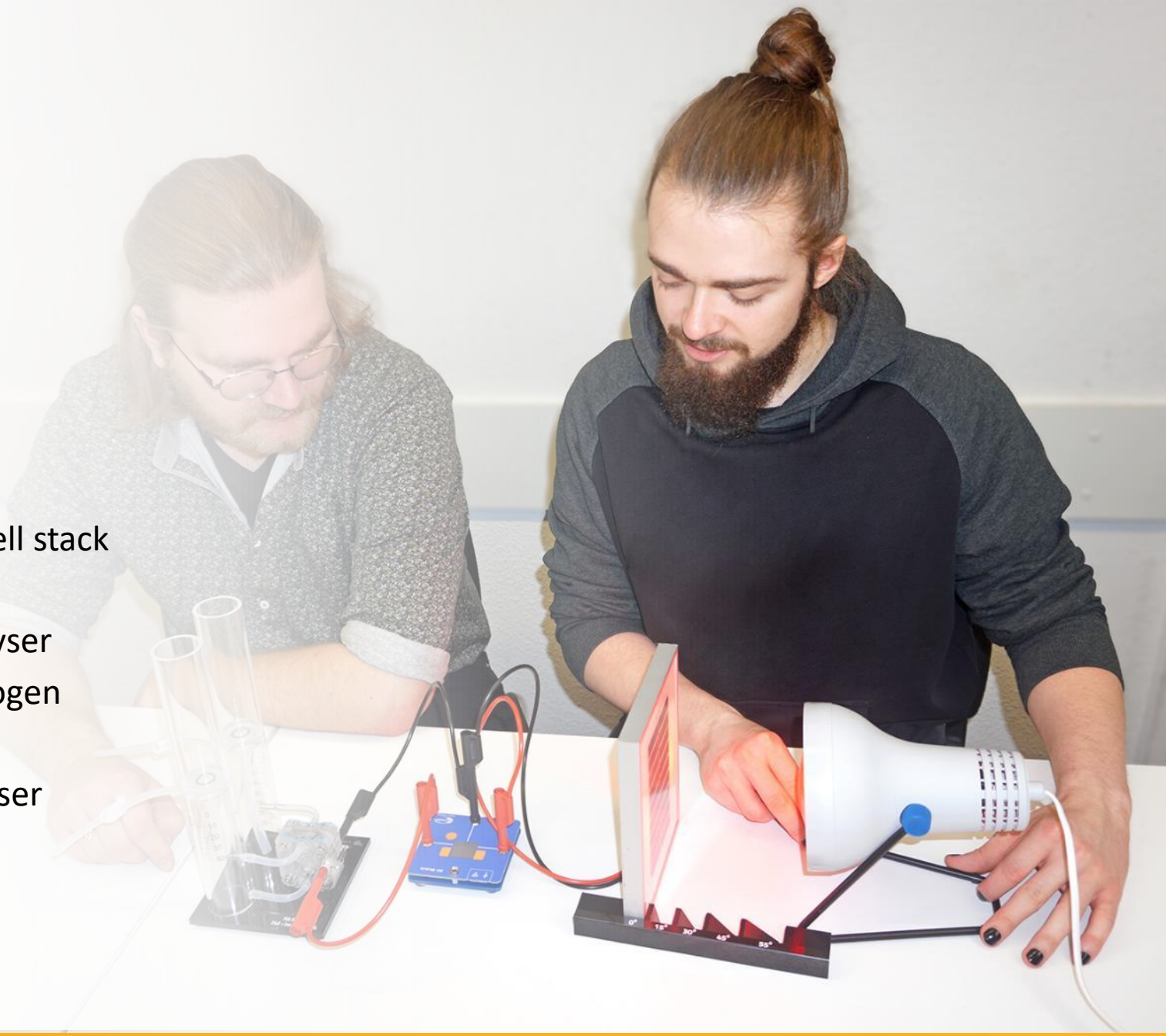
- Fundamentals of electrolysis
- Working principle of PEM fuel cells

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: H_2 Advanced

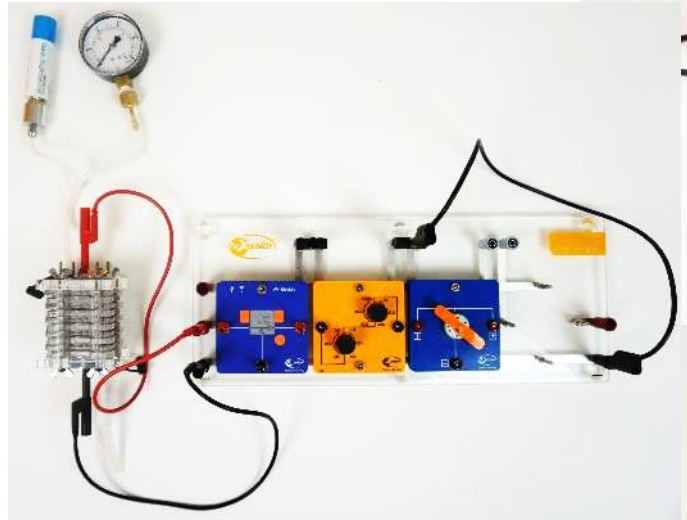
- Double cell electrolyser
- Fuel cell stack (1-5 cells)
- Model car
- Base unit
- Solar cell module 5,2 V with stand
- Infrared lamp
- Potentiometer
- AV module
- Power module
- Blower fan
- H_2 storage (metal hydride, 30 bar, 10 l)
- One-step pressure regulator
- Adapter 2 mm/4 mm
- Short circuit plugs
- Safety cables (4 mm), adapters
- Aluminum case

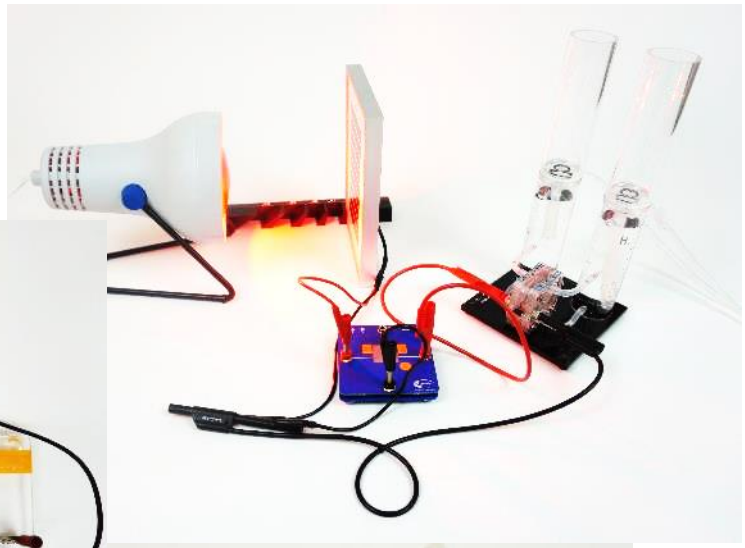
H_2 Advanced: Experiments

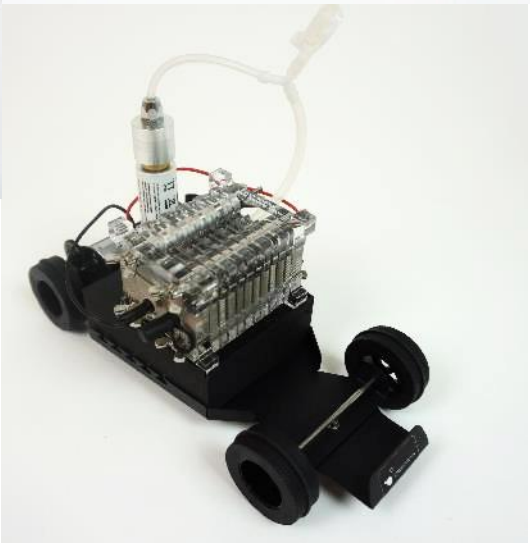
- **Basic experiments:**
  - I-V characteristics of the solar cell
  - Dependence of the solar cell power on the temperature
  - Dependence of the solar cell power on the illumination intensity

- **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

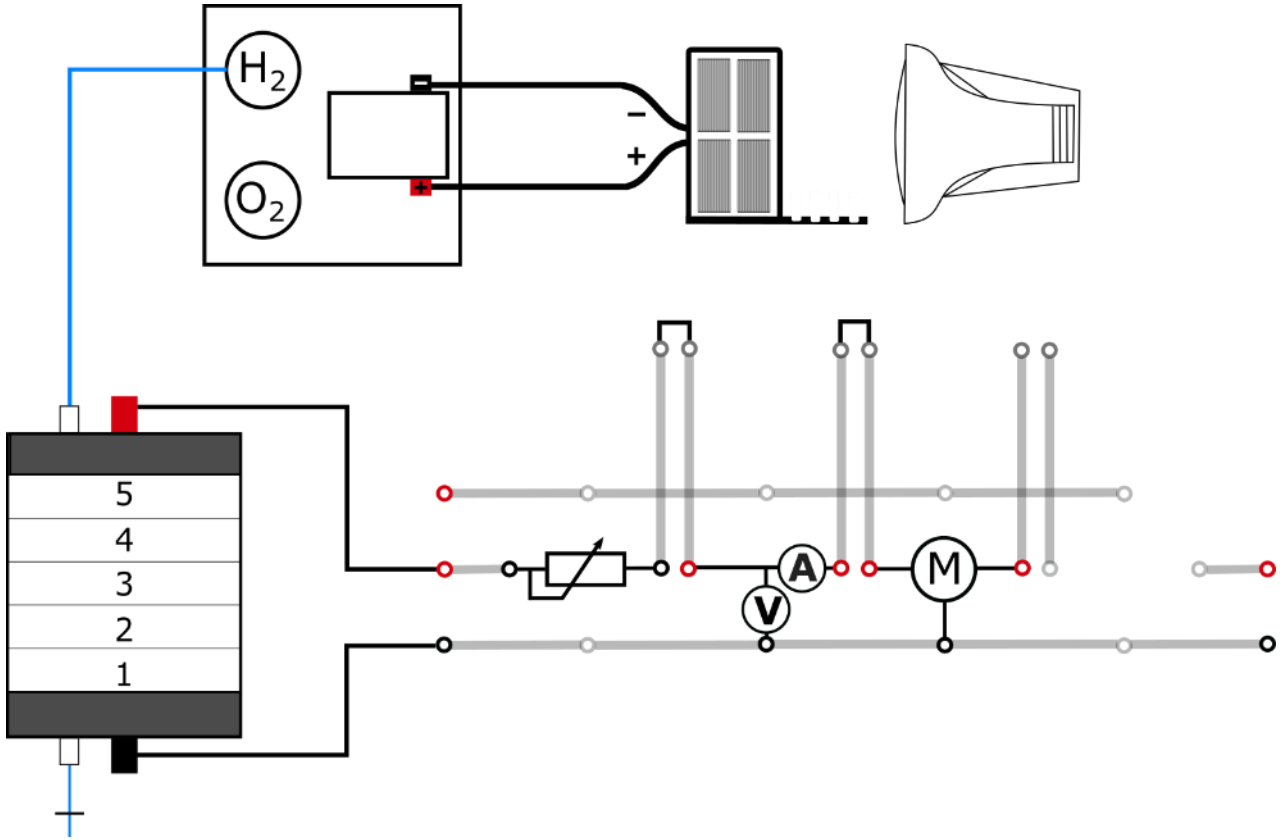






H_2 Advanced: Green Hydrogen Production

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: H_2 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

H_2 Expert: Components

Fuel cell stack:

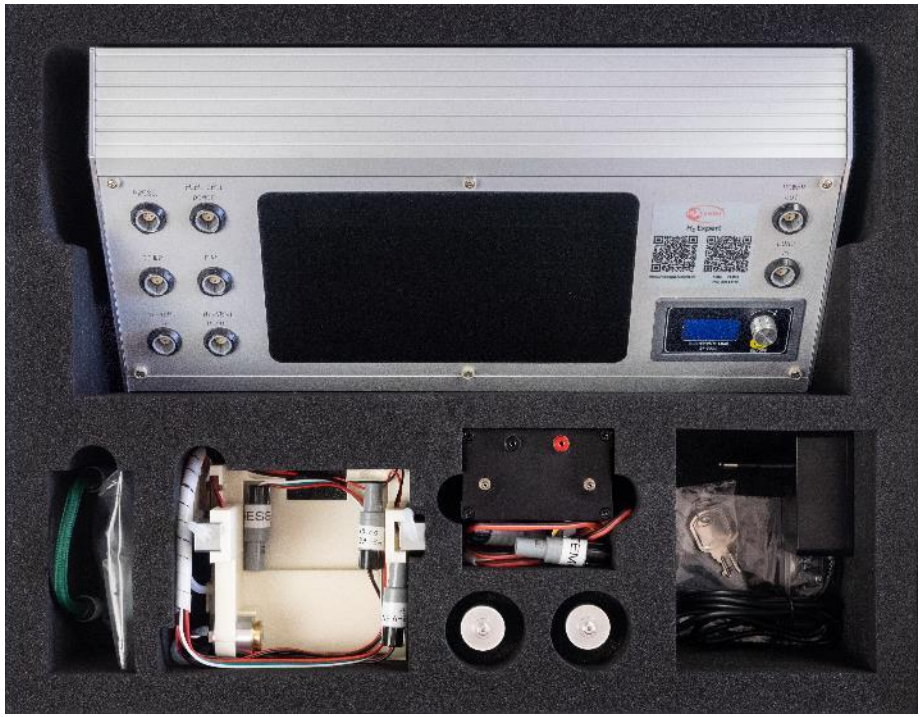
- Type: Proton Exchange Membrane (PEM)
- Nominal power: 20 W (7.6 V @ 2.6 A)
- Open circuit voltage: 12 V
- Start-up time: ≤ 30 s (25 °C)
- Maximal stack temperature: 55 °C
- H_2 pressure: 0.4 - 0.6 bar

Controller:

- Contol unit for the fuel cell
- Data acquisition (cell temperature, H_2 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



H_2 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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