

Interreg VI – A Italia - Österreich  
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# Water to Watts: A Hands-On Hydrogen Mini- Workshop

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**Interreg**  
Italia – Österreich



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**EDU-CIRC**

Author: Semih Bajrami

Company: CUAS

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Name	Organization	Role	Action	Date
Alexander Berndt	CUAS	Lead	Approval	

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V1.1	20/08/2025	Presentation Slides prepared	Semih Bajrami
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# 1. Introduction

This workshop introduces participants to the future-oriented topic of hydrogen in the energy transition. By conducting hands-on experiments with electrolysis and a PEM fuel cell, learners explore how hydrogen can act as an energy carrier in sustainable systems. The session supports conceptual learning and bridges science with real-world applications, safety awareness, and potential career relevance.

## 1.1 Learning Objectives

- Understand hydrogen as a sustainable energy carrier
- Learn the principles of electrolysis and fuel cell operation
- Explore voltage, current, and gas production relationships
- Build awareness of hydrogen's industrial potential and safety aspects
- Encourage scientific thinking and teamwork

## 1.2 Required Knowledge

- No prior knowledge is required
- A basic understanding of electricity and chemical reactions is helpful

# 2. Workshop Structure

Table 1: Workshop structure

Phase	Duration	Activities	Purpose	Materials
Opening	15 min	Intro: EDU-CIRC, Sustainability	Set the context and ensure safety	Slides, images, goggles, gloves
Presentation	10-15 min	Presentation: Hydrogen & Sustainability	Set the context	Slides
Main Experiment	15 min	Electrolysis: Produce H <sub>2</sub>	Observe real-time chemical reactions	PEM Electrolyzer
Second Experiment	25 min	Use PEM fuel cell to power fan/LED, discuss applications	Show hydrogen-to-electricity conversion	PEM Fuel Cell
Wrap-up	10-15 min	Discuss what can be changed in experiment setup to produce more H <sub>2</sub> and electricity.	Share learning and insights	Flipchart, feedback sheets

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### 2.1 Workshop Agenda

Table 2: Workshop agenda

Time	Activity	Format	Duration	Materials	Facilitator Notes
0:00-0:10	Welcome & Brief about EDU-CIRC	Group discussion	10 min	Name tags, whiteboard	Create welcoming atmosphere, ask general question (e.g., what is sustainability?)
0:10-0:25	Presentation: Hydrogen & Sustainability	Presentation	10-15 min	Slides	Cover: H2 basics, H2 from sustainability aspect, advantages and disadvantages
0:25-0:30	Safety Rules Brief	Presentation	5 min	Safety information sheet	Explain safety rules
0:30-0:55	First Experiment: Electrolysis	Hands-on	30 min	Experiment Setup 1	Produce H2 with small setup
0:55-1:20	Second Experiment: Fuel cell	Demo	15 min	Experiment setup 2	Produce electricity with H2 with using fuel cell
1:20 – 1:30	Wrap-up & Presentation	Group discussion	10-15 min	Flipchart, feedback cards	Review what affects gas output and fuel cell performance

### 2.2 Required Equipment

Table 3: Required Equipment

Category	Item	Quantity	Purpose	Alternative Options
Technology	Projector/screen	1 set	Presentations	Large monitor, flip charts
Experiment	DIY Fuel Cell Science Classroom Pack	1 set per group	Hands on activity	Electrolysis setup, PEM fuel cell
Experiment	AA batteries	2 per set	Hands on activity	/
Documentation	Feedback & evaluation forms	1 set per person	Final wrap-up and reflection	Online form or worksheet

### 2.3 Evaluation Framework

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Table 4: Workshop Evaluation

Evaluation Type	Timing	Method	Key Metrics	Follow-up Actions
Immediate	End of workshop	Feedback forms	Understanding of core concepts	Adjust future scenarios for better clarity
Short-term	1-2 weeks later	Reflection survey	Recall of hydrogen learning points	Share real examples of eco-friendly sourcing
Long-term	3-6 months later	Email check-in	Whether students apply sustainability reasoning	Offer further learning materials or case studies

## 3. Detailed Explanation

### 3.1 Opening

0:00-0:10

- **Organizing the room**
- **Brief information about Edu-Circ**
- **Opening speech:**

**Note:** I think it's good to write an opening speech which will be used in all workshops about EDU-CIRC.

### 3.2 Presentation

0:10-0:25

#### Slide 1: Hydrogen: A Sustainable Alternative Energy Resource

**Speaker Notes:** "Good [morning/afternoon] everyone, and welcome to our workshop on *Hydrogen: A Sustainable Alternative Energy Resource*.

We are here today as part of the EDU-CIRC initiative???(how we name ourselves), which focuses on advancing knowledge in sustainability, circular economy and decarbonization. Today our goal is to explore how hydrogen, as a clean and versatile energy carrier, can contribute to a more sustainable future.

Firstly, we will look at the global challenges driving the need for alternative resources, and then shift our attention to hydrogen—its advantages, production methods, challenges, and its role-potential in achieving Net Zero emissions by 2050."

#### Slide 2: Why Sustainability Matters

Speaker Notes: "Ask applicants what is sustainability and why it matters? "

#### Slide 3: Limited Natural Resources

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**Speaker Notes:** “Our population and living standards keep rising, which increases demand for energy, materials, water, and land. That pressure challenges how we design and use products. Sustainability isn’t just ethical; it’s a design constraint that affects cost, risk, and resilience.

Those needs have historically been met by fossil fuels—let’s look at that challenge next.”

### Slide 4: Environmental Challenges

**Speaker Notes:** “Climate change, air pollution, and biodiversity loss are outcomes of how we produce and consume. Engineering choices—materials, processes, and product use—directly influence these impacts. Small improvements at scale can yield large benefits.

So, what’s the engineering role in changing that trajectory?”

### Slide 5: Engineering’s Role

**Speaker Notes:** “Our job is to deliver function with less energy and fewer resources over the full lifecycle—manufacture, use, and end-of-life. That means efficiency, durability, reparability, and circularity.”

### Slide 6: Global Primary Energy Consumption

**Speaker Notes:**

“The energy system has transformed dramatically since the Industrial Revolution. We see this transformation of the global energy supply in the graph shown here. It graphs global energy consumption from 1800 onwards.

Demand for energy is growing across many countries in the world; If this increased demand is not offset by improvements in energy efficiency elsewhere, then our global energy consumption will continue to grow year-on-year. Growing energy consumption makes the challenge of transitioning our energy systems away from fossil fuels towards low-carbon sources of energy more difficult: new low-carbon energy has to meet this additional demand and try to displace existing fossil fuels in the energy mix.

- Reference for speech: Ritchie, H., Rosado, P., & Roser, M. (2020). *Energy production and consumption*. Our World in Data.”

### Slide 7: The Challenge with Fossil Fuels

**Speaker Notes:**

- “Global CO<sub>2</sub> emissions from all sectors have significantly increased since 1850. The majority of this increase has resulted from increased fossil fuel consumption and industrial emissions. Agriculture, deforestation, and other land-use changes have been the second-largest contributors.
- Emissions of non-CO<sub>2</sub> greenhouse gases (CH<sub>4</sub>, N<sub>2</sub>O, and F-gases) have also increased significantly since 1850.
- Globally, greenhouse gas emissions continued to rise across all sectors and subsectors, most rapidly in the transport and industry sectors.”

### Slide 8: Hydrogen as a Future Energy Resource

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### Speaker Notes:

“We’ve looked at sustainability and the challenges of conventional resources. Now, let’s shift to hydrogen, which is gaining attention worldwide.

Hydrogen is now considered to be the future form of leading energy system and multipurpose industrial raw material due to its significant potential to shape building a cleaner and sustainable earth for the human being. (The future of hydrogen: Challenges on production, storage and applications)

In the next slides, we’ll look at its production, challenges, and for future potential.”

### Slide 9: Key Advantages

#### Speaker Notes:

“Hydrogen has a central role in helping the world reach net-zero emissions by 2050 and limit global warming to 1.5 degrees Celsius. (*Hydrogen for net-zero: A critical cost-competitive energy vector*. Hydrogen Council (2021, November))

From now through 2050, hydrogen can avoid 80 gigatons (GT) of cumulative CO<sub>2</sub> emissions.

In terms of end uses, hydrogen is critical for decarbonizing industry (e.g., as feedstock for steel and fertilizers), long-range ground mobility (e.g., long range passenger vehicles, and trains), international travel, heating application, and power generation.”

### Slide 10: Production Methods of Hydrogen: GREY Hydrogen

- **Speaker Notes:** “Grey hydrogen is produced from natural gas through steam methane reforming (SMR). The problem is that it releases large amounts of CO<sub>2</sub> directly into the atmosphere.
- Nearly all of the world’s current supply of hydrogen is created from fossil fuels made through steam methane reforming. In this process, hydrogen is produced from a chemical reaction between steam and methane, the main component of natural gas. Producing one ton of hydrogen through this process emits 6.6–9.3 tons of carbon dioxide.”

### Slide 11: Production Methods of Hydrogen: BLUE Hydrogen

#### Speaker Notes:

- “Blue hydrogen also comes from natural gas using SMR, but with carbon capture and storage (CCS) technologies. This reduces CO<sub>2</sub> emissions by capturing and storing them underground instead of releasing them.
- It’s considered a transition option—cleaner than grey but not fully sustainable.”

### Slide 12: Production Methods of Hydrogen: GREEN Hydrogen

#### Speaker Notes:

- “Most commonly, green hydrogen is defined as hydrogen produced by the electrolysis of water, using renewable electricity.
- Electrolysis is splitting water into hydrogen (H<sub>2</sub>) and oxygen (O<sub>2</sub>). The process has 55–80% efficiency.

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- It produces **zero direct CO<sub>2</sub> emissions**, making it the cleanest option and central to net-zero strategies.
- Producing a kilogram of hydrogen through electrolysis requires around nine liters of water.

### Slide 13: Challenges

**Speaker Notes:** “Let’s look what is the challenges of Hydrogen.”

### Slide 14: Challenges: Cost

**Speaker Notes:** “When comparing hydrogen production methods, the long-term environmental impacts and costs vary significantly. Table presents a comparison of production costs and associated emissions for various hydrogen production processes.

- Grey hydrogen, the cheapest option (USD 0.67–1.31/kg H<sub>2</sub>), has a significant environmental drawback, emitting 8.5 kg CO<sub>2</sub> per kg of hydrogen produced.
- Blue hydrogen offers a middle ground, costing USD 0.99–2.05/kg H<sub>2</sub>, with much lower emissions (2 kg CO<sub>2</sub>/kg H<sub>2</sub>) due to carbon capture and storage (CCS), making it a viable transitional option
- Green hydrogen, produced via electrolysis, is emission-free but costly, ranging from USD 2.28–7.39/kg H<sub>2</sub>. However, as technology advances, the cost is expected to decrease.”

### Slide 15: Challenges: Storage

**Speaker Notes:**

- “Another big challenge is storage. Hydrogen has a very low volumetric energy density, which means that to store enough of it, we either need to compress it at very high pressures or liquefy it at extremely low temperatures. Both of these methods are technically feasible, but they come with high costs and significant energy losses.
- Advancing storage technologies is key to unlocking hydrogen’s full potential and cementing its place in a sustainable energy future. (Hydrogen as an alternative fuel: A comprehensive review of challenges and opportunities in production, storage, and transportation)”

### Slide 16: Challenges: Safety

**Speaker Notes:** “Hydrogen safety is a key concern because it is highly flammable, leaks easily due to its small size, and burns with an almost invisible flame. This makes detection and prevention crucial, requiring advanced sensors, strict handling standards, and robust storage systems.”

### Slide 17: Future Potential

**Speaker Notes:**

- “As we look toward the future due to Net Zero by 2050 report which is published by International Energy Agency, hydrogen’s role in the energy system is expected to grow rapidly. In 2020, global hydrogen-based fuel production stood at just 87 million tons. By 2030, this figure is projected to more than double to 212 million tons, showing how quickly investment and adoption are accelerating. Looking even further ahead, by 2050 production could reach 528 million tons, making hydrogen a cornerstone of the global energy transition.
- This growth highlights hydrogen’s strategic importance for achieving net-zero emission targets.”

## 3.3 Hands On Activity

### 3.3.1 Slides for Activity

0:25-0:30

#### Slide 1: Introduction to PEM

**Speaker Notes:** “Show the real PEM from our setup and start to explain: “Before our hands-on activity I will explain you what is PEM and how it works, then we will start to our activity”

#### Slide 2: Introduction to PEM

**Speaker Notes:** “PEM stands for Proton Exchange Membrane. It is a special polymer membrane that allows protons ( $H^+$ ) to pass through while blocking electrons.

This property makes two opposite applications possible:

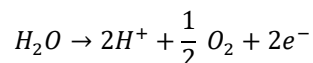
- In a PEM fuel cell, hydrogen and oxygen combine to produce electricity and water.
- In a PEM electrolyzer, electricity is used to split water into hydrogen and oxygen.

PEM systems typically operate at relatively low temperatures (50–80°C). They are efficient, compact, and environmentally friendly, since their only by-product is pure water.”

#### Slide 3: PEM Electrolysis

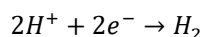
**Speaker Notes:** “A PEM electrolyzer works by using electricity to split water into hydrogen and oxygen.

At the anode, water molecules are split into protons ( $H^+$ ), electrons ( $e^-$ ), and oxygen gas ( $O_2$ ):



The oxygen is released as a by-product at the anode. The protons ( $H^+$ ) pass through the PEM membrane toward the cathode, while the electrons ( $e^-$ ) flow through the external circuit because of the applied electrical energy.

At the cathode, the protons and electrons recombine to form hydrogen gas ( $H_2$ ):

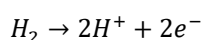


The overall result is the production of oxygen at the anode and hydrogen at the cathode, with hydrogen stored as a clean energy carrier. In summary, a PEM electrolyzer uses electrical energy to split water molecules, producing hydrogen and oxygen.”

#### Slide 4: PEM Fuel Cell

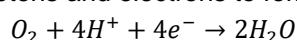
**Speaker Notes:** “A PEM fuel cell works by converting hydrogen and oxygen into electricity, with water as the only by-product.

At the anode, hydrogen molecules split into protons ( $H^+$ ) and electrons ( $e^-$ ):



The protons ( $H^+$ ) pass through the membrane to the cathode, while the electrons ( $e^-$ ) cannot cross the membrane. Instead, the electrons flow through an external circuit, generating electric current.

At the cathode, oxygen reacts with the protons and electrons to form water:





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The outputs of this process are electricity, heat, and pure water. In summary, a PEM fuel cell provides clean energy by electrochemically combining hydrogen and oxygen.”

### Slide 5: Workshop

**Speaker Notes:** “Now you know theoretically how it works. Let’s see how it works practically.”

## 3.3.2 First Experiment: Electrolysis

**0:30-0:55**

**Electrolysis Lab:** Use DIY Fuel Cell Science Classroom Pack and produce Hydrogen.

## 3.4 Second Experiment: Fuel cell

**0:55-1:20**

**Fuel Cell Demonstration:** Use produced hydrogen and produce electricity with PEM Fuel cell.

## 3.5 Wrap Up

**1:20-1:30**

**Wrap-Up Session:** In the final 10 minutes, participants reflect on what they learned, present their findings if done in groups, and discuss the relevance of hydrogen in the future of clean energy. This helps consolidate learning and boost retention.