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Teaching laboratory exercises for analizing the performance of a proton exchange membrane electrolyzer in hydrogen generation systems

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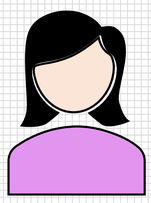
Introduction



Why is it even worth studying or getting into renewables?

Well, they never run out and they're eco-friendly. Plus, let's face it, oil isn't going to last forever.

Fair point. But there's got to be a catch, right?

If we look at wind and solar : first, they're still struggling to compete with fossil fuels in terms of cost. Second, they're super variable.

I get the cost part, but … variable?

Yeah, like, the wind doesn't always blow and the sun doesn't always shine when you actually need power. That's why storing that energy is such a big deal.

And how do you even do that?

By using the electricity they pull in to make hydrogen gas through water electrolysis.

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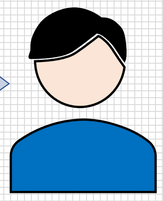
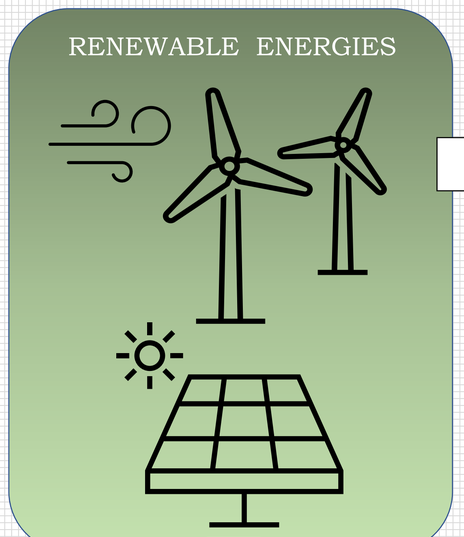
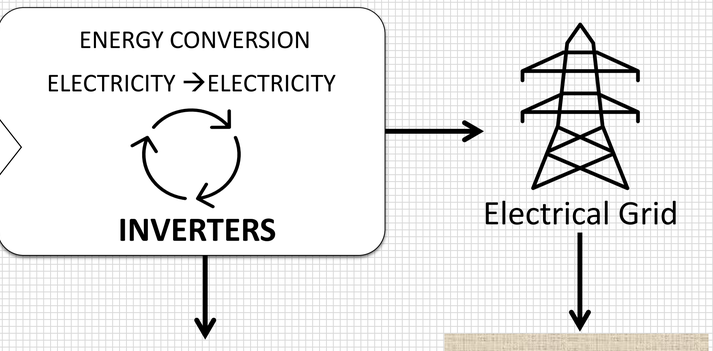


Basically, you turn the energy into hydrogen, and you can store that gas for later.

Does that have its own downsides too?

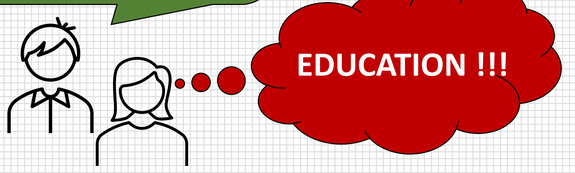
Storing, H2 is definitely tricky, but honestly? I think the real challenge is getting future engineers like us trained up and ready to handle it.





ENERGY CONVERSION
ELECTRICITY→H2
PEM

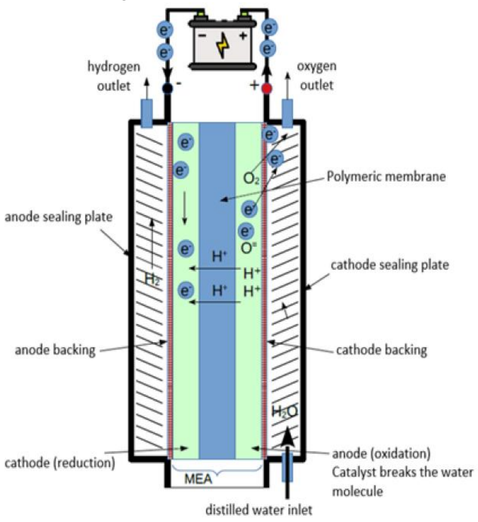
???
¿What technology is used?
¿Devices? ¿parameters?
¿How are they related?

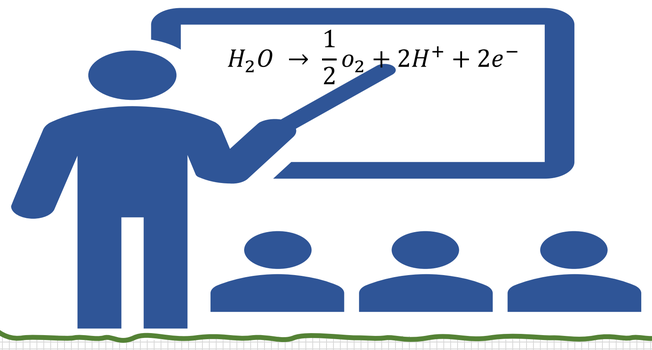


Objective:
Green H_2
Energy buffering
Long-term storage

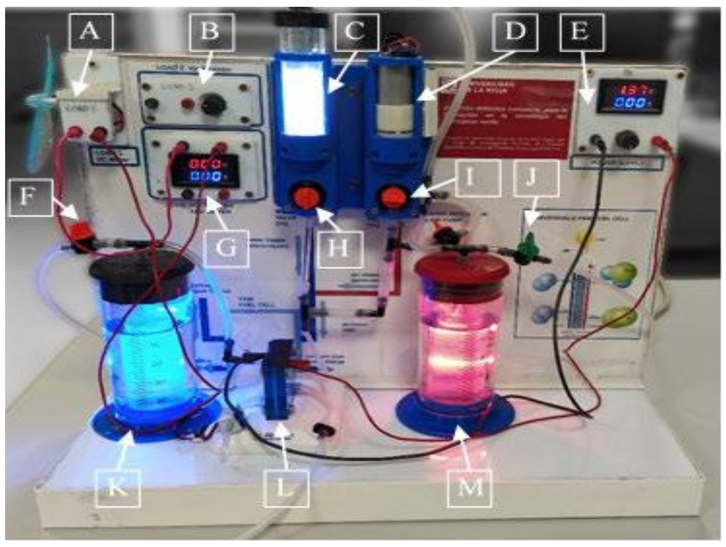
Execution of the laboratory teaching session

1º.- Operation of a PEM electrolyzer.





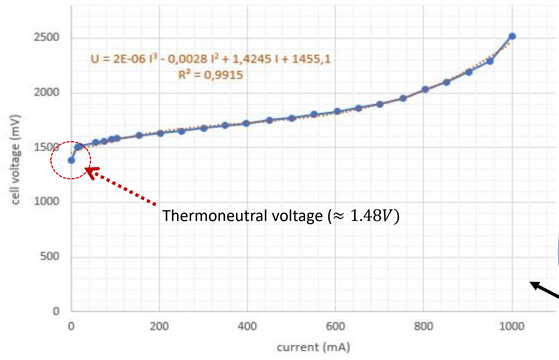
2º.- Description of the educational kit.



A.- electrical load 1
B.- electrical load 2
C.- water reservoir
D.- low-pressure air pump
E.- regulable power supply
F.- valve (hydrogen reservoir)
G.- voltage and current display
H.- valve of the water reservoir
I.- valve (low-pressure air pump)
J.- valve (oxygen reservoir)
K.- hydrogen reservoir
L.- PEM Electrolyzer
M.- oxygen reservoir

3º.- Activities.

A:-Electrolyzer operating curve (thermoneutral voltage).

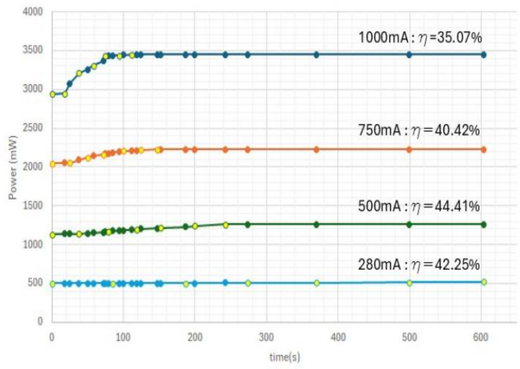


Initial Current → 1 A
…
…
…
Final current → 0 A

voltage and current recording

Voltage-current graph

B:-Stored energy and efficiency of the electrolyzer to different operation currents.



Vol. H_2 (cc)	Time (s)	V cell (mV)	A cell (mA)	Power (mW)	Δt (s)	Energy (J)
test 1						
0	0	2942	1000	2942		
2	18	2950	1000	2950	18	53,10
4	38	3210	1000	3210	20	64,20
6	58	3310	1000	3310	20	66,20
8	75	3430	1000	3430	17	58,31
10	94	3440	1000	3440	19	65,36
12	112	3450	1000	3450	18	62,10
test 2						
0	0	2732	750	2049		
2	25	2740	750	2055	25	51,38
4	50	2830	750	2122,5	25	53,06
6	72	2880	750	2160	22	47,52
8	100	2940	750	2205	28	61,74
10	124	2960	750	2220	24	53,28
12	148	2970	750	2227,5	24	53,46
test 3						
0	0	2269	500	1134,5		
2	38	2280	500	1140	38	43,32
4	79	2340	500	1170	41	47,97
6	118	2390	500	1195	39	46,61
8	152	2430	500	1215	34	41,31
10	200	2480	500	1240	48	59,52
12	242	2520	500	1260	42	52,92
test 4						
0	0	1780	280	498,4		
2	65	1788	280	500,64	65	42,55
4	187	1794	280	502,32	102	51,24
6	274	1803	280	504,84	87	43,92
8	370	1814	280	507,92	96	48,76
10	499	1830	280	512,4	129	66,10
12	603	1853	280	518,84	104	53,96

$$\eta = \frac{E_{H_2}}{E_e} = \frac{LHV_{H_2} \cdot \rho_{H_2} \cdot Vol_{H_2}}{\sum_i V_i \cdot I_i \cdot \Delta t_i}$$

conclusions

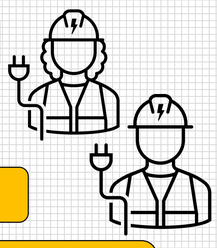
The progressive integration of renewable energy sources into the power system introduces significant challenges due to the inherent variability of their generation.

Hydrogen production from renewable energy (solar and wind) and its subsequent storage are emerging as a solution to the intermittency of these sources.

Future engineers responsible for planning and operating power systems must be adequately trained in the principles, operation, and integration of these technologies.

These principles align with European Commission guidelines on transforming excess renewable energy into a manageable resource and incorporating learning about these types of technologies into university curricula.

This kit enables undergraduate students in renewable energy integration courses to acquire key competencies in hydrogen production and storage.



GRUPO PLOCEL
Planificación, Operación y Control de Sistemas de Energía Eléctrica

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