

SELF-POWERED BUILDING USING HYDROGEN AS AN ENERGY CARRIER

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ABSTRACT

Hydrogen, with its zero-emission potential, is vital in transitioning to sustainable energy. This research aims to investigate and model the potential of hydrogen production and usage as a cleaner energy source for the Hydrogen Research Laboratory building in the METU Chemical Engineering Department. The project's approach is to satisfy the building's energy demand during the day by using clean solar energy with PV panels, then converting it to hydrogen using a PEM electrolyzer and storing it as an energy carrier in the PEM fuel cell when solar energy is unavailable. In this context, the total power consumption was determined in three different scenarios, considering the energy required for the laboratory building's heating, cooling, and appliances. Three scenarios are named: average demand, peak demand in summer, and peak demand in winter, and power demands were found as 40.9 kW, 113.7 kW, and 46.8 kW, respectively. The required hydrogen amount to satisfy these rates was found to be 2.4 kg-H₂/h on average demand, 6.5 kg-H₂/h for peak demand in summer, and 2.7 kg-H₂/h for peak demand in winter. Necessary PV cell units and areas were found as 14 units-37 m², 39 units-101 m², and 16 units-42 m², respectively. Also, this research evaluates storage type regarding safety, economic, and feasible aspects by investigating five cases for storage: metal hydride and compressed gas at different pressures.

INTRODUCTION

The project's methodology is to use solar energy in the laboratory building and store it as hydrogen with water electrolysis when it is sufficient in the daytime. For the times when solar energy is inaccessible or insufficient, stored hydrogen is used as an energy source. The flowchart of Figure 1 illustrates this interaction. For this purpose, this project focused on three distinct scenarios to find the required energy and hydrogen demand for different cases. Furthermore, research focuses on the five different storage types to compare them regarding safety, economy, and feasibility.

Three different scenarios:

- Scenario 1 is based on **average conditions** for one year.
- Scenario 2 is based on **summer peak demand** when the air temperature is 40 °C.
- Scenario 3 is based on **winter peak demand** when the air temperature is -15 °C.

Five different storage types:

- Type 1 is **metal hydride** at 10 bar & 25 °C and 0.82 m³
- Type 2 is **compressed gas** at 30 bar & 25 °C and 0.05 m³
- Type 3 is **compressed gas** at 30 bar & 25 °C and 1 m³
- Type 4 is **compressed gas** at 300 bar & 25 °C and 0.02 m³
- Type 5 is **compressed gas** at 700 bar & 25 °C and 0.05 m³

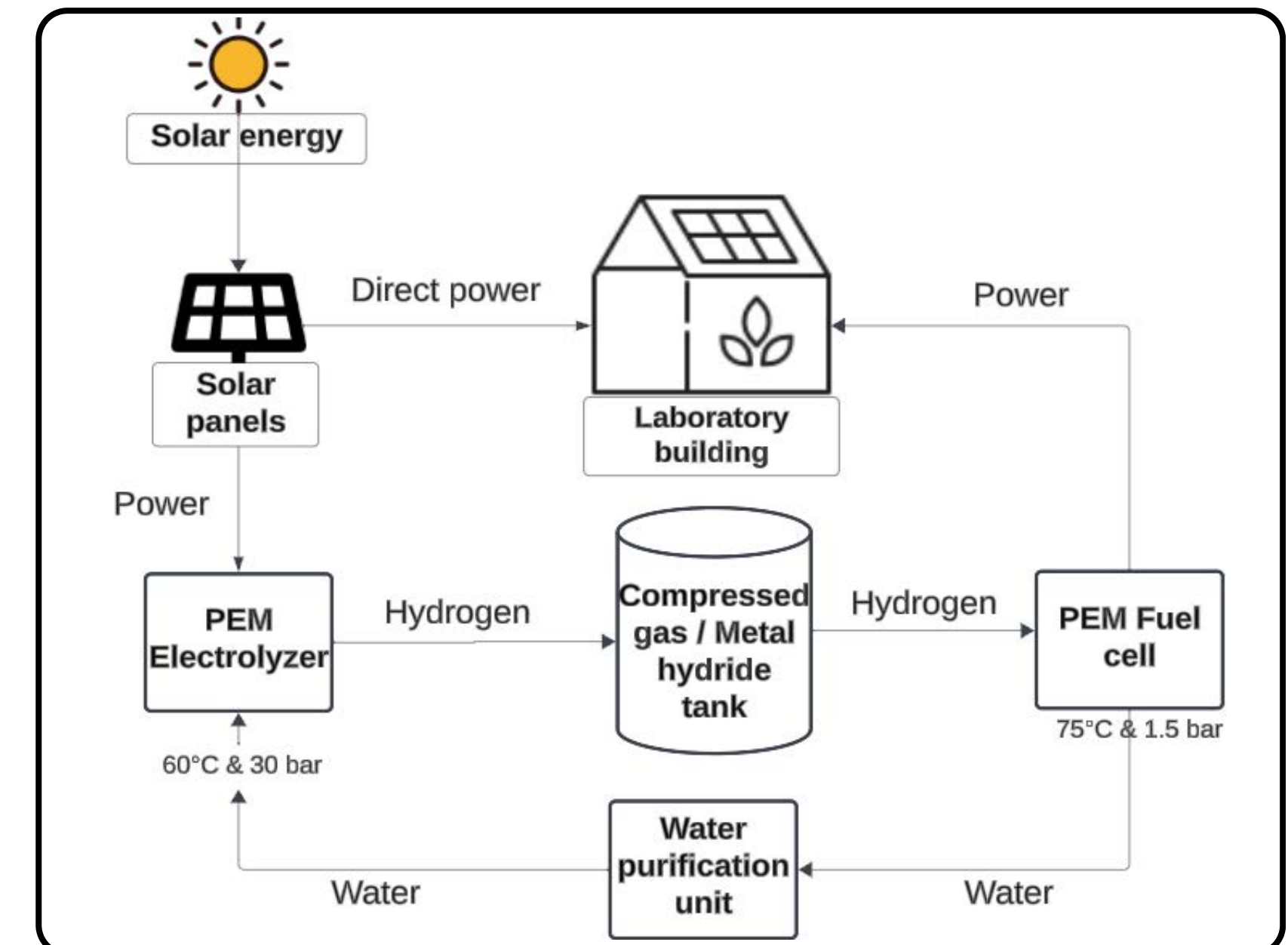


Figure 1. Flowchart of the hydrogen production and usage as an energy source

RESULTS AND DISCUSSION

Results of three different scenarios are given in Table 1. It was decided that the whole system should be set up according to the summer case otherwise, the amount of hydrogen produced during the daytime does not meet the required power demand at night [1].

Table 1: Three different scenarios for average, summer and winter demand

	Average demand	Winter peak demand	Summer peak demand
Instantaneous energy demand (kW)	40.9	46.8	113.7
Fuel cell hydrogen demand (kg/h)	2.4	2.7	6.5
Electrolyzer energy demand (kW)	103.5	118.5	288.1
Electrolyzer water demand (kg/h)	15.72	18.0	43.8
Solar panel unit and area(m ²)	14 solar panels 37 m ²	16 solar panels 42 m ²	39 solar panels 101 m ²

Figure 2 shows the summer cases' working principle and how much hydrogen is to be stored on a daily basis, and Figure 3 shows the average power consumption (40.86 kW) distribution and percentages.

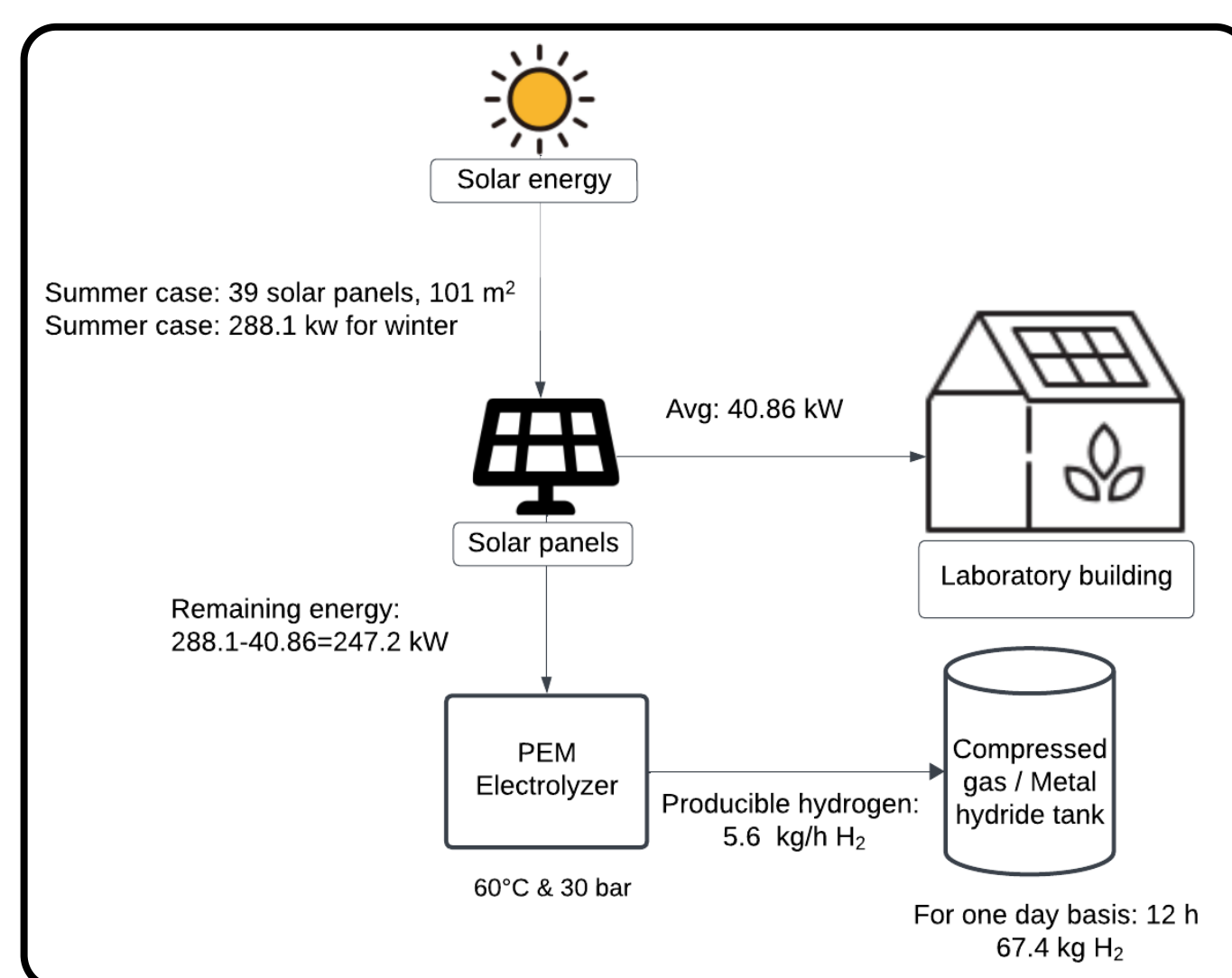


Figure 2. Flowchart of the summer case

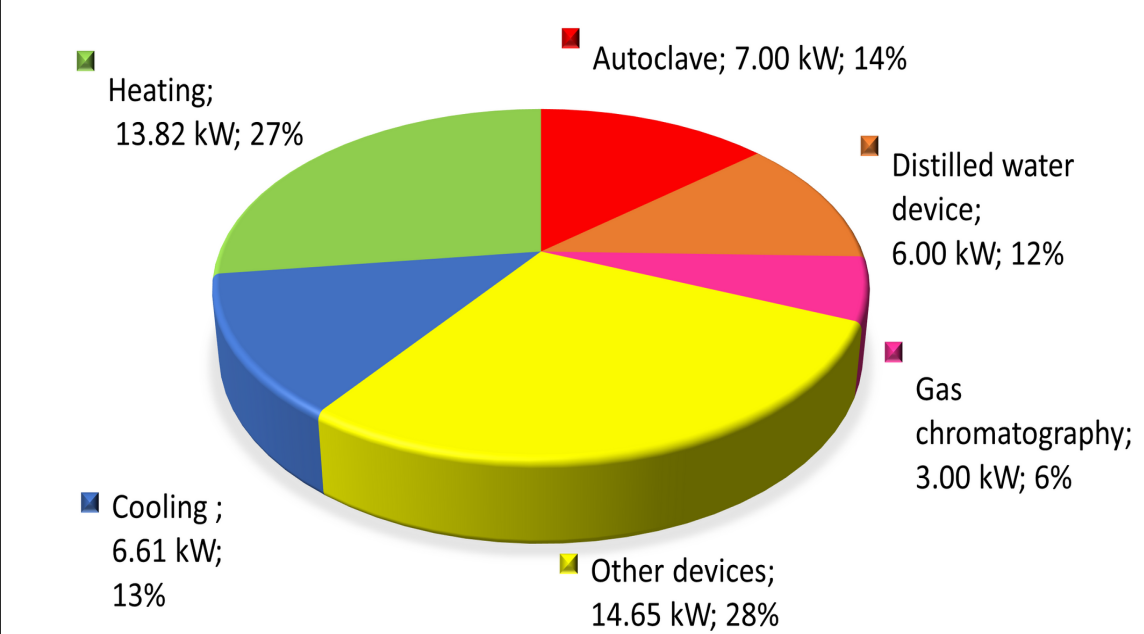


Figure 3. Distribution of average power consumption

A comparison of the five different storage types based on the mass of the storage, 67.4 kg H₂ are shown Table 2. Data compiled from [2, 3, 4, 5, 6].

Table 2: Five different scenarios types of storages

	Metal hydride (10 bar & 25°C)	Compressed gas cylinder (30 bar & 25°C)	Compressed gas cylinder (30 bar & 25°C)	Compressed gas cylinder (300 bar & 25°C)	Compressed gas cylinder (700 bar & 25°C)
Storage density (kg/m ³)	0.81	2.40	2.40	21.15	41.52
Tank volume (m ³)/capacity (kg)	0.82/0.66	0.05/0.12	1/2.4	0.02/0.42	0.05/2.28
Number of tanks	103	562	29	160	30
Cost of one tank (\$)	3,980	100	23,000	137	1,500
Total tank cost (\$)	410,000	56,000	667,000	22,000	45,000

- **Least cost:** CG at 300 bar & 25 °C and 0.02 m³
- **Safest:** MH at 10 bar & 25 °C and 0.82 m³
- **Most compact:** CG at 30 bar & 25 °C and 1 m³

The storage type is chosen as CG at 30 bar & 25 °C, and 1 m³ because it is the safest and most compact type, and there is no need to use a compressor after the PEM electrolyzer. The table below shows the equipment cost for the summer peak demand scenario. Additionally, the graph in Figure 4 indicates the total PEC and other elements of CAPEX, which is 2.7 million \$ while OPEX is 38 thousand \$.

Table 3: Purchased equipment cost [7, 8, 9, 10]

Equipment	Cost (\$)
PEM fuel cell	200,000
PEM Electrolyser	230,000
PV cells (39 units)	7,800
Water treatment unit	8,500
CH gas cylinders (30 bar & 25 °C-1m ³) (29 units)	667,000
Total PEC (million \$)	1.1

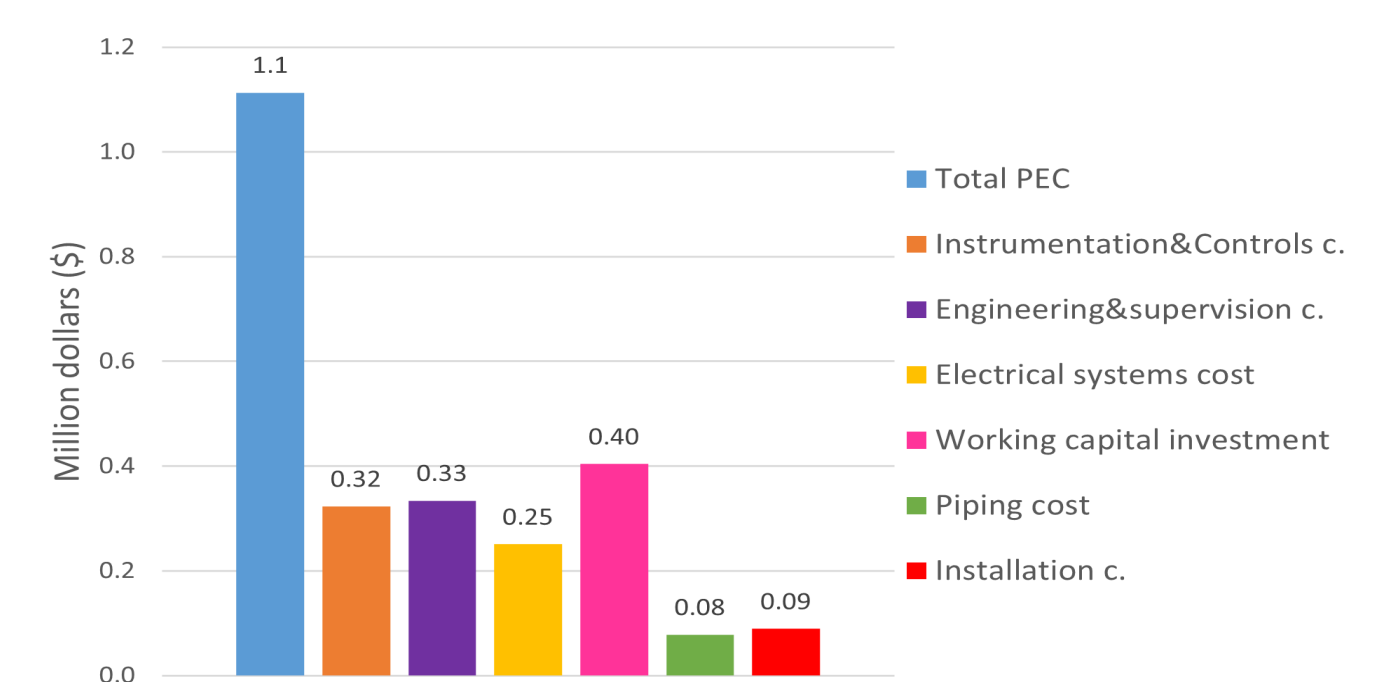


Figure 4. Elements of CAPEX

CONCLUSION

This project focuses on supplying all energy demands of the Hydrogen Research Laboratory using green hydrogen energy as a self-powered building. For this purpose, three different cases were evaluated: the average demand scenario, the summer peak demand scenario, and the winter peak demand scenario. It is shown that establishing the system according to the summer peak demand supplies enough hydrogen for all times of the day. Summer peak case system can produce 5.6 kg-H₂/h in the daytime, and 67.4 kg H₂ should be stored. Furthermore, five different storage types are investigated. CG at 30 bar and 25 °C and 1 m³ were chosen for the storage because of safety and compatibility issues. CAPEX and OPEX costs of Peak Demand in Summer Case & CG at 30 bar & 25 °C and 1 m³ found 2.7 million dollars and 38 thousand \$/year accordingly.

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