Global Scientific JOURNALS

GSJ: Volume 12, Issue 5, May 2024, Online: ISSN 2320-9186
www.globalscientificjournal.com

# Using technical analysis of physical environments in the electrolysis of hydrogen from off-grid photovoltaic cells

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**Abstract.** The electrolysis of water using solar energy to produce hydrogen has become a viable strategy for decarbonizing the global energy economy. However, this area is more expensive than conventional hydrogen production for fossil fuels, and it is necessary to identify effective ways to reduce these costs. Here we describe the Monte Carlo approach, which allows us to study a wide range of initial assumptions to identify the main cost factors, goals and local conditions necessary for competitive independent specialized hydrogen electrolysis in photovoltaic installations. We determine the level of hydrogen costs, taking into account historical weather data for specific sites, to model our photovoltaic system and optimize its size compared to an electrolyzer. This analysis and its methods demonstrate the possibility of environmentally friendly hydrogen production using autonomous photovoltaic systems, demonstrate the benefits of remote systems in areas with high solar energy consumption, and provide cost and performance targets for electrolysis technologies

**Key word:** Electrolysis, Global energy, Monte Carlo approach, Photovoltaic, Physical Environment, LCOH, Green hydrogen.

**Introduction:** Renewable energy sources such as wind and solar energy are the key to decarbonizing the electricity sector. However, these renewable sources operate intermittently and are often located remotely, which requires large investments in storage and transportation at high throughput [1]. The conversion of this renewable energy into hydrogen provides a unique solution to this problem, since this hydrogen can act as an energy carrier, as well as be used as a raw material for production (for example, oil refining, ammonia production, chemical production) [2]. One of the main advantages of hydrogen (compared to other energy storage systems such as batteries and pumped hydroelectric power plants) is its portability, since the fuel can be easily liquefied and exported in a similar way to LNG or mixed with natural gas for transportation using existing distribution infrastructure. Currently, most of the global demand for hydrogen (estimated at 80 metric tons per year) is provided by cheap hydrogen produced from fossil fuels (through steam reforming of methane and coal gasification) [2]. However, more recently, the introduction of stricter environmental policies, such as carbon capture and storage requirements and/or a carbon tax, may shift these applications towards environmentally friendly hydrogen. Goals, strategies and roadmaps for the hydrogen economy are being studied all over the world, and the European Union is launching a hydrogen roadmap in Europe. Australia is once again focusing on clean (low carbon) hydrogen as part of the National Hydrogen Strategy , which describes Australia as having great potential for hydrogen production and export, especially to Japan and South Korea, which are heavily dependent on energy imports. It recognizes the possibility of producing pure hydrogen in Australia through coal gasification and SMR, along with electrolysis of water using renewable electricity [3]. Due to the complexity and limitations of CCS in place, the first option has not yet resulted in any large-scale demonstration projects. However, for the latter, several hydrogen electrolysis development projects have been launched in Australia: a renewable ammonia plant in the Yarra Pilbara; the South Australian Hydrogen Park, which aims to add hydrogen to the natural gas network; and a hydrogen and ammonia supply chain demonstrator in Port Lincoln, which will include two turbines burning hydrogen gas. In connection with the planned further projects, there is a need to develop business models for electrocatalytic hydrogen production that will guide the development of the industry [4]. Previous work in this area has focused on comparing electrolyzer technologies and determining the cost of hydrogen in specific regions around the world. These economic estimates take into account electricity generated from the electric grid (which can be generated from conventional thermal or solar photovoltaics, biomass or hydropower), dedicated photovoltaics, and dedicated photovoltaics supplemented with grid electricity.For example, the National Hydrogen Roadmap of Australia predicts that the average consumption of hydrogen will be between $3.25 and $3.97 per kilogram (all monetary values in this article are given in US dollars [USD], using an alkaline electrolyzer using electricity prices reflecting the premium Charge for renewable energy plus the best hypothetical scenario of $1.89/kg. Similarly, a recent study conducted in Canada using network electrolysis, simulated a low ratio of $2.93 to $3.22 per kilogram in Ontario using artificial intelligence.9 These reports highlight the attractiveness of networked hydrogen electrolysis because it allows electrolyzers to operate with high power factors and even take advantage of the negative price in the event of peak oversupply due to the high power of photovoltaic installations [2] [3]. Studies considering the case of custom electrolysis using photovoltaic cells usually make simple assumptions about fixed arbitrary power coefficients, usually do not take into account solar insolation data for a specific object, and many of them do not take into account strategies to increase the power coefficients of the electrolyzer due to the appropriate size of the photovoltaic module. for example, Shaner et al. reported BTU for USD 12.1/kg when using paired photovoltaic analyzers, but with a low power factor of 20% and with high capital costs for an electrolyzer for 900 USD/kW. the International Renewable Energy Agency (Irena) estimated that the average fuel consumption in Australia ranges from $3.77 to $4.34 per kilogram with a power factor of 30% [5]. As a rule, there is a wide range of LCOH values calculated from literature data, based on different configurations and different assumptions for the main input parameters. Due to this knowledge gap, it becomes necessary to develop a comprehensive framework not only to identify the main cost and productivity factors worldwide, but also to study and assess the impact of the main cost and productivity factors that will allow renewable hydrogen generation to compete with fossil fuel-based hydrogen generation. This model of operation has a major drawback, which is the negative effect on the power factor of the electrolyzer, but the advantage is that it allows you to install large systems in remote locations where there is no connection to a high-power network. This avoids the often high costs of connecting to the network and the risk of delays both in the physical connection and in the approval process. These delays have been a major problem for some modern utility-scale photovoltaic systems in Australia, as well as for renewable energy projects in the Netherlands [6]. To determine LOCH, we consider the actual electricity generation of a photovoltaic system based on historical weather data (and possible future trends) for

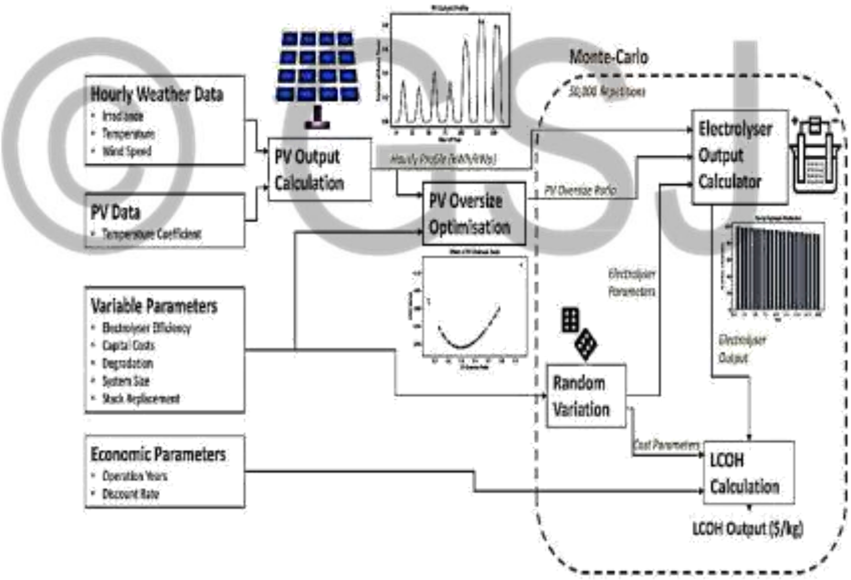


**Figure 1. Model Flow Diagram**

Flow diagram describing the technical and economical model of the Monte Carlo analysis. Calculations within the Monte Carlo section are done for 50,000 iterations and those outside are calculated only once.

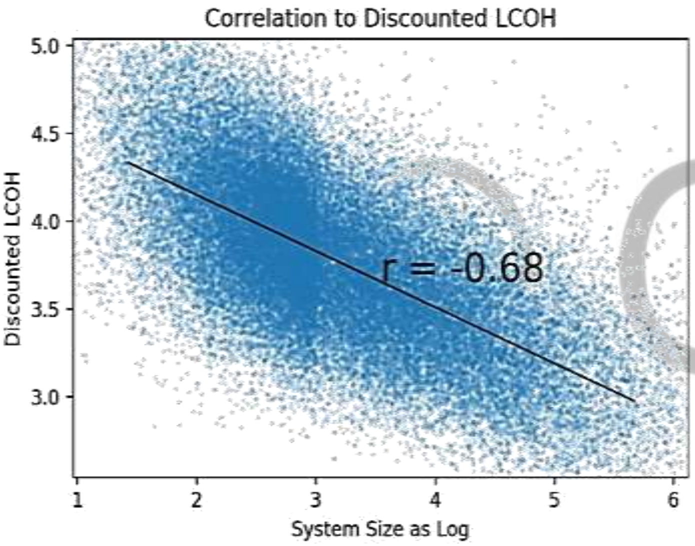
Determine the location and optimization of the size of the PV power plant (compared to the electrolyser) and the output power factor of the electrolyser. We created a basic model for the city of Townsville (a coastal city in Australia) providing a wide range of values for system size, capital cost and electrolyser efficiency to examine the key factors for LCOH reduction. We also demonstrate the applicability of this model to a remote site in Australia and a number of countries around the world [6]. Our findings show that regions with high solar resources, such as Port Hedland (in outback Western Australia) and Chile, show the potential to produce hydrogen via photovoltaic electrolysis at much lower costs than other locations, especially Japan, which is expected to generate strong demand. For clean hydrogen. Finally, an evaluation comparing proton exchange membrane (PEM) electrolysis and AE is performed, which evaluates the combined effect that differences in electrolyser capital costs and electrolyser efficiency have on the choice of the optimal technology. According to preliminary results, it is clear that system size, capital cost, and electrolyser efficiency are the three basic and most important factors for LC-OH. The parameter space is explored to identify scenarios in which LC-OH could be competitive with fossil fuel processes such as SMR ($2.5/kg14) [7]. Regions with high solar resources, such as Port Hedland (in remote Western Australia) and Chile, show the potential to produce hydrogen via photovoltaic electrolysis at much lower costs than other locations, especially Japan, which is expected to have strong solar demand. energy [6] [7]. Pure hydrogen. PEM electrolysis is competitive with AE only when improved cell efficiencies and costs are balanced within the specific ranges identified in this work.

1. **Key Drivers to LCOH Reduction** This is when LCOH analysis is adopted, and the Monte Carlo method that was used in this model helps in determining the parameters that have the largest and most important impact on the final LCOH. In this work, each input parameter of the model varies randomly based on the values given in (Table 5), and the output LCOH is determined for each iteration. A regression analysis is then completed for all input variables in order to determine the factor that has the greatest impact on LCOH, the results of which can be seen in Table 1. Our results show that the size of the electrolyzer system (the correlation is calculated using a logarithm due to the scaling factor model described in the experimental procedures) is the largest factor influencing the change in the calculated LCOH, with a variance (r2 value) of 46%. The scattering diagram in (Fig. 2) shows this strong negative correlation, suggesting that with a 10-fold increase in rated power, there is a significant decrease in the corresponding LCOH by 0.3 USD/kg (according to linear fitting estimates). This concept of economies of scale is well supported by the literature for both photovoltaic installations and electrolyzers. For example, Bruce et al. It is estimated that an increase in scale by 1000% (equivalent to an absolute change in the logarithm of rated power by 3.0%) could reduce the cost of level zed by more than $1.0/kg [8]. Thus, policy efforts to demonstrate larger photovoltaic hydrogen production projects of the order of hundreds of megawatts could help reduce LCOH, as they encourage manufacturing companies to scale up. The range of possible electrolyzer efficiencies considered in the model also affects the LCOH. This was to be expected, since increased efficiency leads to an increase in hydrogen production per year at the same capital cost and, consequently, to a decrease in LCOH [7]. Thus, this is a key area of research for improving not only alkaline electrolysis, but also TEM and high-temperature electrolysis, which are reported to have higher theoretical efficiency, although they require higher capital costs. However, the ranges of photovoltaic and capital costs for the electrolyzer considered in this model have less impact on the final LCOH if these two factors are combined into a parameter of total capital costs (total capital costs per 1 MW are shown in( Figure 2).

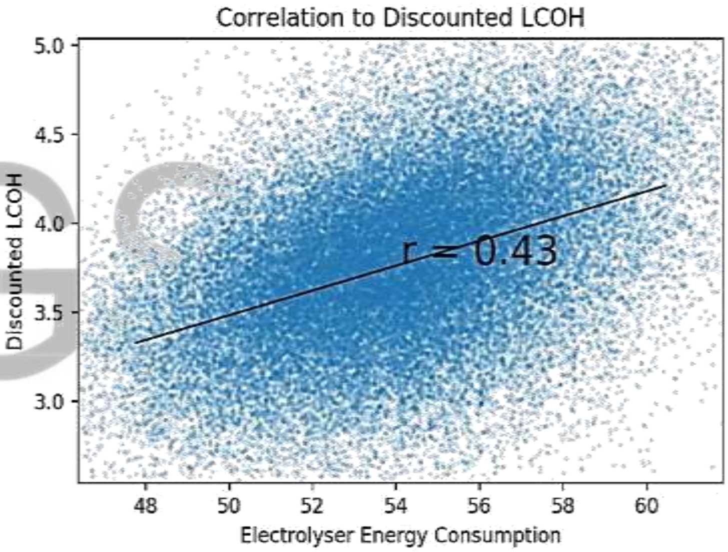
**Table 1**. Variance Contribution for the Top 5 Impacts on the LCOH

| Parameter | Unit | Input range(10th-90th percentile) | Variance(%) |
|---|---|---|---|
| Log of electrolyzer system size | | 2–5 (100 kW–100 MW) | 46 |
| Electrolyzer efficiency | kWh/kg H2 | 50–58 | 19 |
| PV CAPEX (1 MW) | $/kW | 682–886 | 15 |
| HElec CAPEX (1 MW) | $/kW | 682–886 | 6 |
| PV OPEX | $/kW/year | 6.82–13.6 | 3 |
| Electrolyzer OPEX | $/kW/year | 13.6–20.5 | 1 |

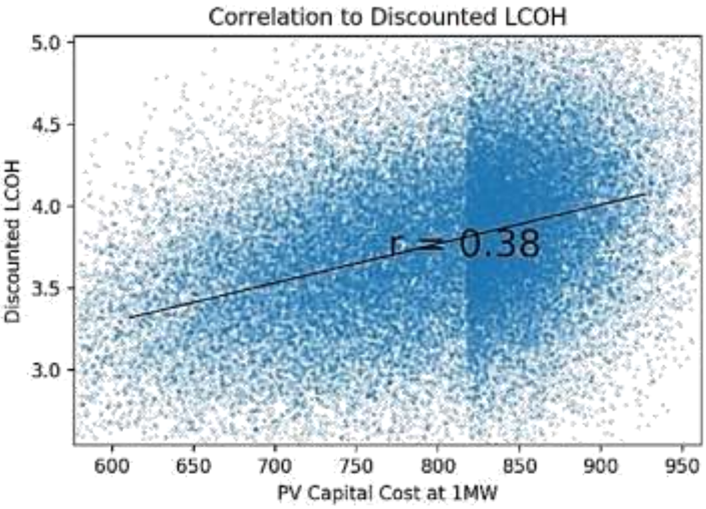
The variance is calculated as the r2 value for the correlation



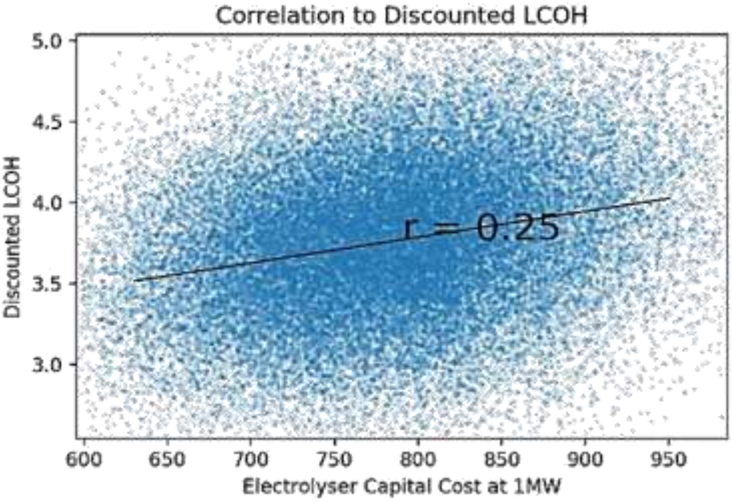
**A. Log of electrolyser nominal power**



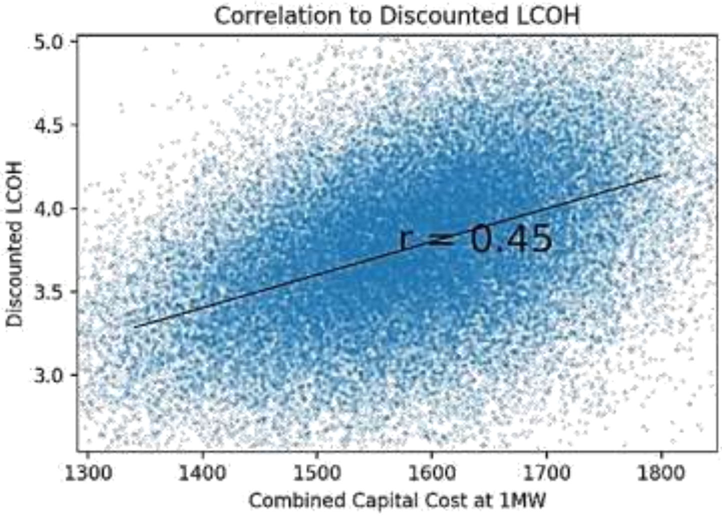
**B. Electrolyser energy consumption (kWh/kg-H2)**



**C. PV capital cost (at 1MW size) ($/kW)**



**D. Electrolyser capital cost (at 1MW size) ($/kW)**



**E. Combined capital cost (at 1MW size) ($/kW)**

**Figure 2.** Scatter plots showing the impact of the most influential parameters on the LCOH

This new parameter is responsible for 20% of the change in LCOH, exceeding the correlation due to electrolytic efficiency. Please note that total capital expenditures are expected to be significantly reduced in the future. The costs of photovoltaic systems have decreased very rapidly as the volume of production has increased, according to learning rate models (lower prices per multiple of total production). Unit prices fell by more than 60% from January 2014 to January 2020, while, according to recent estimates, the level of training was 23.2%. Prices for photovoltaic batteries are expected to fall further as they continue to be installed in Australia and around the world [7]. The cost of the electrolyzer is also expected to be based on the learning rate model, and the learning rate can be estimated at 18% with different uncertainties. [9]. If this pace of learning continues, then we can expect a significant reduction in capital costs for electrolysis as the industry grows and larger projects are implemented. Although this is not directly included in the form,. We discuss and determine the impact of this reduction in tuition fees on the World Health Committee. An important parameter that did not change during the Monte Carlo analysis was the introduction of weather data due to short-term fluctuations from year to year or long-term climate change [7].The average standard deviation of annual insolation in Townsville calculated over the past 30 years is 4.1%, which does not show a long-term trend. If this pattern continues, the use of data for a typical Meteorological year for each year in the 20-year model of the College will give an average representative value for the college, since years of higher and lower photovoltaic power generation will be largely nullified. However, this is not true if climate change has led to a change in average insolation. To also get an idea about the effect of this change on the results in general, a parallel analysis was performed to compare the calculated LCOH values based on different weather profiles for different latitudes. such as Townsville (19.3 s south latitude), keeping all other variables constant at their nominal values. The results of this analysis show that different levels of annual illumination change the power factor of the electrolytic and, accordingly, the louver (Figure 2) [8]. For example, Antananarivo, Madagascar (18.9 km to the south) receives more precipitation and global horizontal radiation is 10.4% lower than in Townsville, resulting in global horizontal radiation levels 21% higher. While Broome, Australia (18.0= South) is drier, it experiences a 12.0% higher

GI and issued a token that was 12% lower compared to Townsville. The most important thing was that although we obtained a large difference, climate change may take such a long time and therefore will have an impact mainly on the last years of operation. This result provides some indication of how climate change will affect the environment [7] .

To understand the interaction between the three parameters and to find out which of them is the most important (as shown in Table 1 and Figure 2), we work to establish a correspondence between the logarithm of the estimated power, the conversion efficiency, and the total variable capital costs (Figure 3), since the LCOH lines are installed at specific capitalization (x-axis), system size (y-axis), and electrolyser efficiency (four subheadings). It can also be noted that, in an alternative form, the measured capital costs of PV installations (x-axis) and measured electrolyzers (y-axis) with different efficiencies are shown in Figure 4.

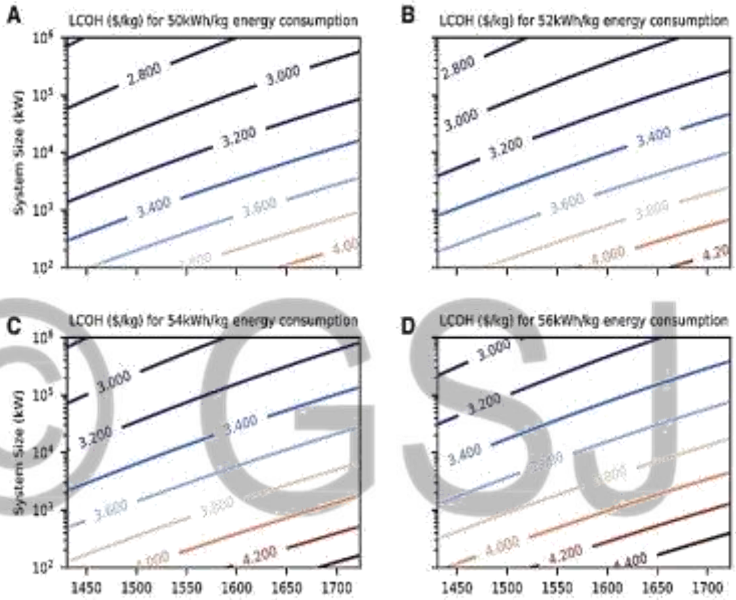


**Figure 3..** Contour Plot of the Key Variables

Impact of the economies of scale and the capital costs on the LCOH at various electrolyzer efficiencies.

(A) 50 kWh/kg H2.

(B) 52 kWh/kg H2.

(C) 54 kWh/kg H2.

(D) 56 kWh/kg-H2

Using (Figure .3), We can identify current and future scenarios and evaluate their LOCH [4]. Here we define the current scenario as 1 MW with an electrolyzer power consumption of 54 kWh / kg and a total capital cost per 1 MW of USD 1,550 / kW, with an estimate of USD 3.80 / kg. Note that this current 1 MW scenario may reduce the size of the systems, and it is very likely that the larger system sizes will be. For example, at the time of writing, the Australian Renewable Energy Agency (Arena) announced a competition for hydrogen electrolysis projects with a capacity of 5 to 10 MW [3]. The effect of increasing the size of the system on the calculated lke can be seen in( Fig.3) Our results also showed that another way to reduce the louvre is to increase the electrolytic efficiency. If it is possible to combine a larger system with higher-efficiency electrolyzers (52 kW/kg H2), then in a scenario with a high efficiency of 10 MW, only 3.3 USD/kg can be achieved (provided that capital costs remain at current values). Such a high efficiency value may be achievable since some manufacturers of electrolyzers indicate an efficiency of 4.5% kWh / Nm 3 (50.1 kg/kWh H2), although in these cases it was a question of Stack efficiency, which takes into account only the electrolysis process and not the efficiency of the system, which includes energy losses on the balance of the system components, which was determined [9]. Another direction of cost reduction is to reduce the capital costs of both photovoltaic installations and electrolyzers. For example, we can see the impact on health if the total capital expenditure falls by 10% below 1400 USD/kW on a 1 MW scale. To achieve this value by saving only on the electrolyzer, the cost of the electrolyzer should be less than the current estimate. From 8 886 to up to 600 dollars per kW, which is a reasonable expectation of some experts at the current pace of research, development, and implementation. Combining this low cost in the future with the high efficiency of the electrolyzer and very large volumes of the installation, the proposed inexpensive and highly efficient 1 GW scenario has an approximate cost of 2.70 USD/kg, approaching the price mark of 2.50 USD/kg, at which, according to Irina, electrolysis can begin to compete with the production of hydrogen for the production of fossil fuels. In line with this idea, the concept of large-scale hydrogen production centres is widely recognised as a key strategy in Australia [10].

2. **Compared with grid-connected electrolysis the results of this analysis** showed the potential of an independent electrolysis configuration to achieve a low level of electrolysis, similar in value to other studies that assume a grid-connected configuration. However, this in itself does not mean that an offline configuration can be cheaper than a network-connected one [11] [7]. The optimal configuration for any particular situation depends on the specific circumstances of the case. For example, our work shows that reducing the capital cost of an electrolyzer will lead to a decrease in the percentage of electricity, but it will also worsen the appearance of the system connected to the power grid. However, if the project can access the power grid very cheaply, then this would only reduce the Lakh from the configuration connected to the network [11] [5]. The purpose of this work is not to identify the exact

conditions under which an offline configuration is better or worse than a network-connected one. For this comparison, we will consider only the simplified case of a network electrolysis system operating with a high power factor. For each of the 50,000 iterations of our standard model, we added a network-connected configuration that had to be built at the same scale and have the same capital costs for the electrolyzer and operating costs as the standalone configuration. We have studied the ranges of parameters of the network connection fee, the average price of electricity during operation, and the power factor (Table 2). For each iteration, we compare the blinds of the offline configuration with the blinds of the configuration connected to the network and determine the main parameters that determine the best option. This reflects the type of decision-making process that has to be faced when determining the optimal configuration for certain conditions [11].

This analysis revealed the conditions under which an autonomous photovoltaic system is preferable: with large system sizes, low capital costs for photovoltaic systems and high prices for electricity on the grid. Since these parameters dominated the comparison, it is possible to show the relationship between these three parameters and choose the optimal configuration (Figure 5).

**Table 2**. Parameters that were varied for the grid connected electrolysis analysis

| Parameter | Unit | Nominal | Low | High |
|---|---|---|---|---|
| Electricity Price | $/MWh | 47.7 | 34.1 | 68.2 |
| Electrolyser Capacity Factor | % | 95 | 80 | 98 |
| Grid Connection Charge | $/kW | 6.82 | 3.41 | 34.1 |

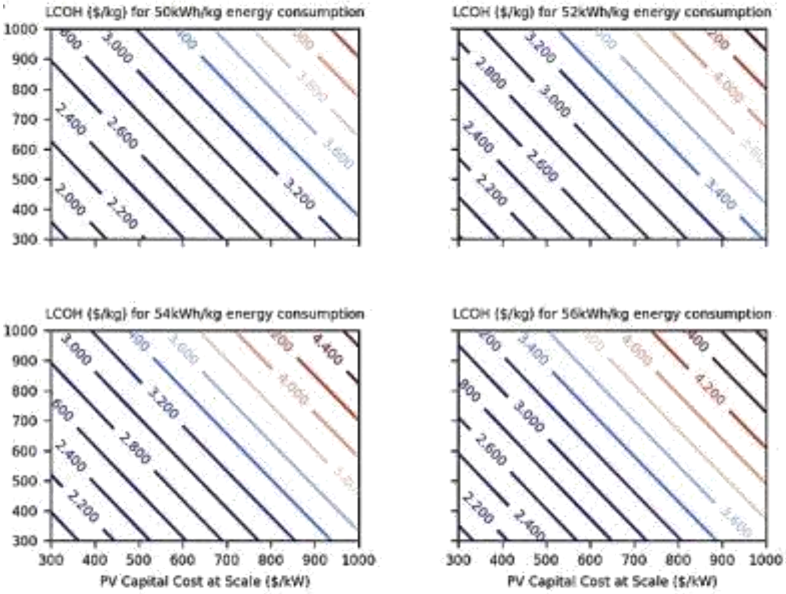


**Figure 4.** Impact of the scaled PV and electrolyser capital costs on the LCOH at various electrolyser efficiencies.

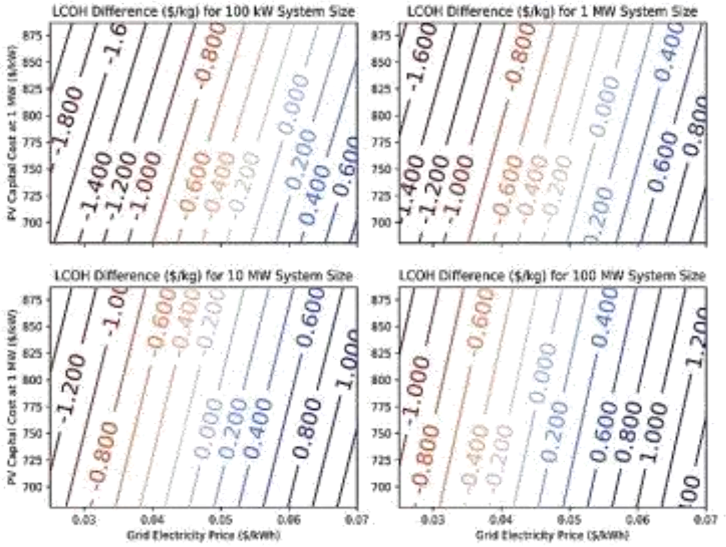


**Figure 5.** Impact of the PV capital costs and grid electricity price on the difference between grid connected and standalone PV LCOH at various system sizes

For example, a specialized electrolyzer powered by a 1 MW photovoltaic system (assuming current capital costs for a photovoltaic installation) will provide a low cost compared to a grid-connected system in an environment where the average price of electricity available to the grid is >0.055 USD/kWh.

Figure 6 shows the output of our model for a number of key input parameters, which we use to compare the expected conditions and the conclusions of two previous studies, which showed that grid-connected electrolysis is much cheaper than autonomous photovoltaic. For Steiner et al., The capital costs of photovoltaic installations at that time.

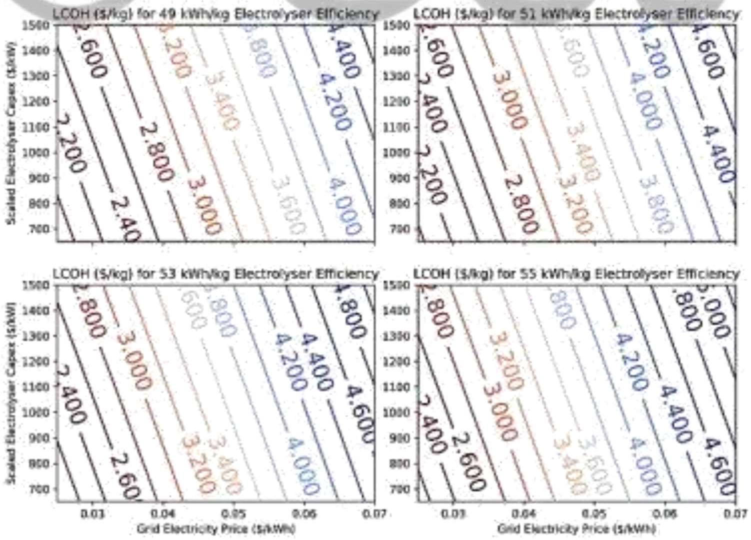


**Figure 6.** Impact of the Electrolyser capital costs and grid electricity price on the calculated LCOH of a standalone PV system at various electrolyser efficiencies (49 - 55 kWh/kg)

**Table 3**. Mean and SD of the LCOH for the Chosen Locations

| Location | Mean LCOH ($/kg) | SD ($/kg) |
|---|---|---|
| Townsville, Australia | 3.93 | 0.52 |
| Port Hedland, Australia | 3.38 | 0.45 |
| Palm Springs, CA, USA | 3.71 | 0.50 |
| Fukushima, Japan | 4.72 | 0.61 |
| Calama, Chile | 3.60 | 0.48 |
| Caceres, Spain | 4.07 | 0.54 |

(2016, $1,400/kW) were almost twice the current values (according to our estimates, $700/kW), combined with an electricity price of $70/MWh (American industrial prices). Our comparison model confirms that a network system is preferable in such conditions. The work of Bruce et al.6 is newer, and their system has much lower capital costs for photovoltaic installations (USD750/kWh) [13], but since it assumes a reduction in electricity prices by $40/MWh (subject to the conclusion of competitive electricity purchase agreements), it also concludes that a connected network is cheaper than an autonomous PV, which is also approved by our model. Our model can be used to evaluate other possible situations. For example, our model predicts that if the prices of inexpensive photovoltaic energy can be recently achieved in an unprotected site, based on the electricity prices estimated by Scheiner et al., then an independent photovoltaic configuration is preferred. This confirms our discovery that the best choice of system for any particular location largely depends on the conditions of that location—iin particular, the average cost of electricity—aand that an autonomous system can have an advantage under the right conditions. Since electricity prices vary greatly depending on the country, location within the country, and over time as regulations and production structures change, it is possible to find and implement independent electrolysis where these conditions are quite suitable [13].

3. **Location Comparison—Worldwide/International** To demonstrate the applicability of the model on a global scale and compare the feasibility of autonomous photovoltaic hydrogen electrolysis in Australia with other regions, a comparative analysis of hydrogen production was carried out in other regions, including 'energy giants' such as the United States and Europe, potential hydrogen economies such as Japan, and regions with large renewable energy resources (Chile and Australia). Specific locations were selected based on hydrogen or solar activity in that area. The sites of Palm Springs, California (USA), and Fukushima, Japan, were chosen because of the proposed megawatt projects for environmentally friendly hydrogen electrolysis in these areas. In the Extremadura region, while studying hydrogen production from autonomous

renewable energy sources, it was found that Calama is the best region for hydrogen production in photovoltaic installations in Chile. An additional location in Australia, Port Hedland, in the Pilbara region, was chosen because it is a proposed major export area. Since the solar profiles of each site are different, the size ratio of the photovoltaic panels has been optimised on a case-by-case basis. The improved large coefficient and all other initial data used in this comparison are presented in Table 4. The proposed (590 MW) solar power plant is located near Caceres, Spain.

**Table 4**. Locational parameters. Table containing the parameters that were varied for the comparison of different locations. An uncertainty range of 10% was to all variables.

| Parameter | Unit | Townsville , AUS | Port Hedland, AUS | Caceres , ESP | Calama, CHL | Fukushima , JPN | Palm, USA | Springs |
|---|---|---|---|---|---|---|---|---|
| Yearly Irradiance | kWh/$m^2$ /yr | 2046 | 2402 | 1665 | 1665 | 1257 | 2045 | |
| PV Oversize Ratio | | 1.50 | 1.38 | 1.59 | 1.35 | 1.56 | 1.51 | |
| PV Capital Cost at 1000kW[15] | $/kW | 880 | 880 | 802 | 740 [6] | 787 | 942 | |
| PV Operating Cost [15] | $/kW/yr | 9.2 | 9.2 | 7.1 | 12.6 [6] | 7.5 | 9.3 | |
| Discount Rate [15] | % | 5.65% | 5.65% | 4.88% | 7.0%[6] | 3.23% | 5.68% | |

**Table 5.** Parameter Values Used in the Monte Carlo Analysis values used in the Monte-Carlo analysis.

| Parameter | Unit | Nominal | Low | High |
|---|---|---|---|---|
| Electrolyzer Parameters | | | | |
| Nominal power | kW | 1000 | 100 | 50000 |
| Capital Cost at 1000 Kw | Kw AC$ / | 784 | 682 | 886 |
| Capital Cost scaling factor | Per 10 – fold size increase | 0.9 | 0.8 | 1.0 |
| Operating costs | Kw/ year $/ | 17.0 | 13.6 | 20.5 |
| Water cost | kL$/ | 1.44 | 1.02 | 6.82 |
| Water usage | L/ Kg $H_2$ | 10 | 9 | 11 |
| Efficiency | kWh / kg $H_2$ | 54 | 50 | 58 |
| Yearly degradation | year% / | 0.30 | 0.10 | 0.50 |
| Stack lifetime | h | 80000 | 70000 | 90000 |
| Stack replacement cost | Of capital cost% | 40 | 35 | 45 |
| PV Parameters | | | | |
| PV to electrolyzer ratio | | 1.5 | | |
| Capital cost at 1000 kW | Kw $_{\text{AC}}\$$ / | 818 | 682 | 886 |
| Capital Cost scaling factor | Per 10 – fold size increase | 0.9 | 0.85 | 0.95 |
| Operating costs | Kw / year$/ | 9.82 | 6.82 | 13.6 |
| Yearly degradation | Year%/ | 0.50 | 0.20 | 0.75 |
| General Parameters | | | | |
| Operation years | Year | 20 | - | - |
| Discount rate | % | 5.75 | - | - |

Current values from literature and industry can reflect nominal values, while low as well as high values reflect uncertainty and possible future values. The low and high values were used as percentages of 10 and 90, respectively, to obtain distributions in the Monte Carlo analysis. The parameters are fixed without high or low values. Distributed hydrogen production from photovoltaic cells in areas with high solar insolation. An additional advantage of remote hydrogen generation is that hydrogen can be used in the local power system since the hydrogen required for hydrogen production in this case is 3.07–3.75 dollars. (United States of America/kg). From this, we conclude that hydrogen can be used in remote areas, especially those with good solar resources, which is very promising. In contrast, Japan regained the highest price for a kidney (4.72 dollars per kilogrammeme), and the average cost difference between the best location in Australia and Japan was 1.34 dollars per kilogrammeme. This suggests that there may be a possibility of exports to Japan if the costs of pressing and transportation can be reduced below this value. According to the National Human Rights Commission, Australia's current costs for liquefaction and transportation are >2.73 dollars per kilogrammeme, with the possibility of reducing them to 1.7 dollars per kilogrammeme (assuming that the transportation distance to Japan is 8000 km), which is still higher than this cost difference. However, if much larger electrolysis systems can be installed in Australia, economies of scale will increase the cost difference, making the Australian option cost-effective [11]. There is reason to believe that the scale of the system in Japan will be limited due to the availability of land and that Japan will still need to import hydrogen, even if it has a large production of cheaper, environmentally friendly domestic hydrogen, because it is a large energy importer and environmentally friendly domestic hydrogen production may not be practical to meet all its energy needs. Given the other places that have been designed, Chile may be able to compete with Australia as a source of hydrogen, and it is considered a hidden champion [12].

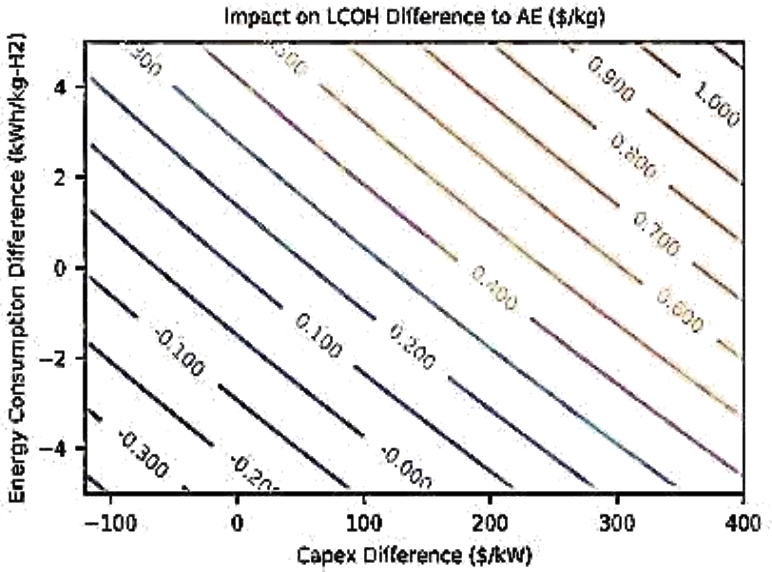


**Figure 7.** Comparison between AE and PEM Technologies LCOH difference between AE and PEM, depending on the difference in capital cost and energy consumption.

World Energy Council. Chile also

has a very high insolation of 2376 kWh / m2 / year and is also known to have strong wind resources, which can allow creation a hybrid wind-solar-hydrogen system with higher and lower energy coefficients

## 4. Technology Comparison—Alkaline Electrolysis versus Proton Exchange Membrane

So far, the use of EA has been hypothesised in this study; however, other electrolytic techniques such as BIM and solid oxide electrolysis cells (SoC) are emerging. Sok is still largely considered unready for commercialization due to its high costs and limited service life [11]. However, bem electrolyzers are being widely developed; a demonstration sample with a capacity of 6 MW is already in operation in Germany; and companies have begun to produce commercial bem electrolyzers. Although the current capital costs for BIM are higher than what is said about Abdullatif, and this gap is narrowing over time (and research), there are estimates that the cost of BIM may eventually become lower than Abdullatif. In addition, it is believed that BIM has advantages in efficiency as well as load flexibility, which can be more suitable for working with variable renewable energy sources. Therefore, it is important to consider how the use of BIM instead of EA can affect things [11] [3]. To simulate two electrolysis techniques, Monte Carlo analysis was performed for both with the same uncertainty ranges of the input data, except for the parameters described in detail in Table 6. The simulation reproduced the cost graphs shown in Figure 8. Although, in the vast majority of iterations, Abdullatif has less to LOCH, Figure 9 shows that in some cases, BIM is Cheaper Than Abdullatif. To determine the parameters that significantly affect the cost difference between Pim and EA, an uncertainty analysis was performed (similar to the section "key factors of LOCH reduction" above) for various variables. This showed that the two most important parameters are the difference in capital expenditure and the difference in energy consumption. (Figure 7) shows a graph of the dependence of the WHC on Abdullatif with different variations in capital expenditure (x-axis) and energy consumption (Y-axis). Many studies predict that the beam technology will have a lower specific power consumption than Abdullatif, optimizing electricity consumption up to (3-4 kWh/kg H2) [2]. As shown in (Fig. 7)

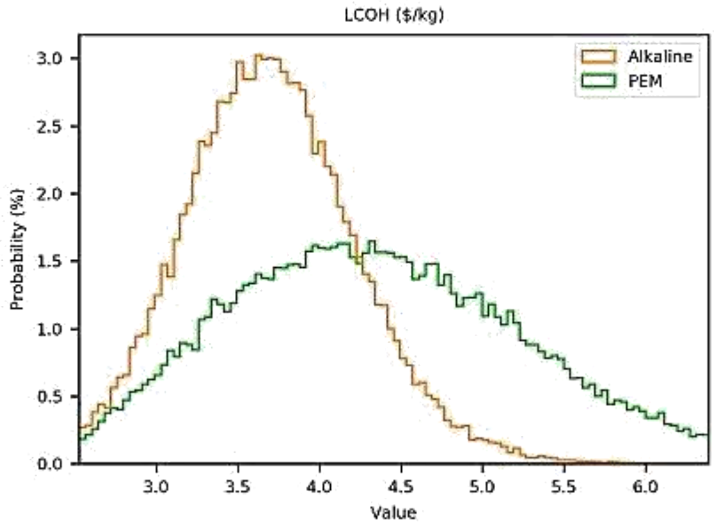


**Figure 8.** LCOH histogram for AE and PEM technologies

**Table 6**. AE vs. PEM parameters. Table containing the parameters that were varied for the comparison between AE and PEM.

| Parameter | Unit | Alkaline Electrolysis | | | Proton Exchange Membrane | | |
|---|---|---|---|---|---|---|---|
| | | Nominal | Low | High | Nominal | Low | High |
| Capital Cost at 1000kW[4,7,16,17] | $/kW | 716 | 614 | 886 | 1227 | 614 | 1704 |
| Energy Consumption [4,7] | kWH/kg-H2 | 54 | 49 | 59 | 52 | 45 | 59 |
| Stack Lifetime [4] | hr | 80,000 | 60,000 | 100,000 | 80,000 | 60,000 | 100,000 |
| Minimum Capacity | % of Rated Power | 10% | 5% | 20% | 10% | 5% | 20% |
| Electrolyser Degradation [17] | %Voltage Rise/yr | 0.30% | 0.10% | 0.50% | 0.70% | 0.50% | 1.0% |
| Operating Costs [17] | $/kW/yr | 17.0 | 13.6 | 20.5 | 17.0 | 13.6 | 20.5 |

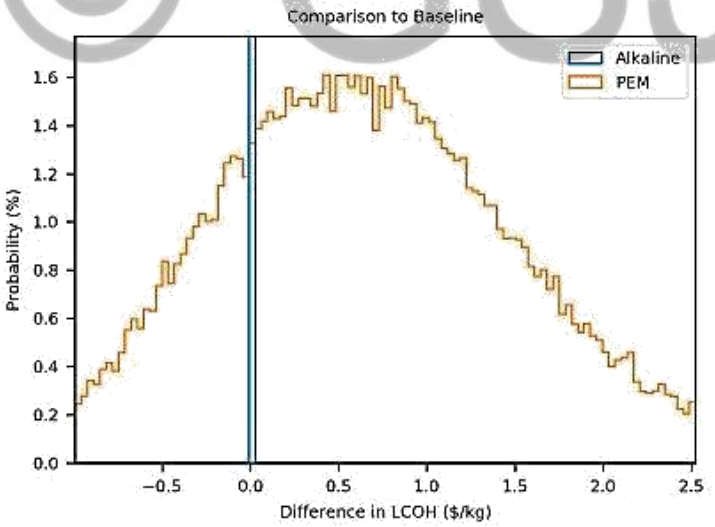


**Figure 9.** Difference between PEM and AE LCOH for equivalent iterations. Those below zero are iterations where PEM is more cost effective than AE

As shown in (Fig. 7), with a more optimistic increase in efficiency (by 4 kWh/kg H2), if the capital cost of the BIM electric Analyzer is at least (100 USD/kW) more than that of A. L. C., There is no point in LEC. Expert estimates at the fiftieth percentile in 2017 predicted that the capital costs of the beam would be at least 110 USD/kW (100 EUR/kW) higher than the costs of Emirates India, which, as this modelling indicates, would not mean an advantage in LCOH . Rather, according to other forecasts, the cost of BIM will be at or slightly cheaper than E. In this case, reducing energy consumption can lead to savings of LC by (0.20 kg/kg) in favour of BIM [11]. This result provides an idea of the required efficiency and cost improvements needed to make beam technology competitive with the UAE. This article marks the first use of multivariate uncertainty analysis applied to the feasibility study of autonomous hydrogen production from renewable sources, giving companies and researchers a tool to find strategies to make autonomous electrolysis using photovoltaic profitable. It was demonstrated that examining a large and wide range of values for different input cost values, provides a quantitative analysis of how these changes affect key variables, which include, for example, system size and energy consumption. and capital costs [11]. By comparing PIM with EA, we can assess how much it is necessary to increase the capital costs and efficiency of PIM to become competitive in the current and projected market conditions. In addition, this model can also be easily applied anywhere using local real-world weather data and has many other applications, such as evaluating whether a gas station can supply itself with hydrogen or whether hydrogen can be integrated into a remote power system. Finally, the analysis makes it possible to assess the export possibilities of renewable hydrogen, reflecting the price difference between production in countries with good insolation, such as Australia and Chile, and countries such as Japan that depend on energy imports [4].

## 5. RESULTS AND DISCUSSION

A model (Figure 1) was created to determine a reduced LCOH for an independent Photovoltaic electrolysis systems are based on capital, operating costs and hydrogen. Production per year for a specific site. Townsville was chosen as the primary choice; However, the model is applicable anywhere internationally using appropriate weather data (described below). A total of 50,000 repetitions of the Monte Carlo analysis were performed , Which allowed us to get a good idea of the possible results without requiring a lot of computational effort.(Figure 10 )shows the results of the location of the Townsville Base, where the average cost of living is 3.72 USD / kg, and the 10th and 90th percentile is 2.89 USD / kg ,And 4.67 USD / kg, respectively. The range of received costs is quite wide, reflecting ,A large set of key input variables is used in Monte Carlo analysis. In particular, This value strongly depends on the size of the system, as discussed in the next section. This difference is reflected in the calculated values in the literature, since each study takes into account different points in time, different locations, etc. Our results ,The model corresponds to other results in the literature, when we adjust the input parameters according to those assumed in this other studies. For example, IRENA estimated an LCOH of ($3.77–4.34/kg $) for electrolysis of low-cost photovoltaic installations in Australia (cost of electrolytic capital: 840 kW/kW, conversion efficiency: 61 kWh / kg, Power Factor: 24%, the cost of aligning electricity from photovoltaic installations: 2 29.8-4 41.2/MWh). If we enter these parameters into our model, we will get .A similar range (3.64-4.25 USD / kg), with a slight deviation due to our strategy. Increase the size of the photovoltaic installation (increase the power factor of the electrolyzer to 34%). In the Australian context, the results highlight the potential feasibility of independent photoelectric electrolysis to achieve the goals of the World Health Commission set by the Australian National Human Rights Commission in the scope of ( 3.26 USD / kg to 3.98 USD / kg ) (pink dotted lines in Figure 10). Another important comparison to note is that our calculated LOCH is higher than that specified for hydroelectric power stations

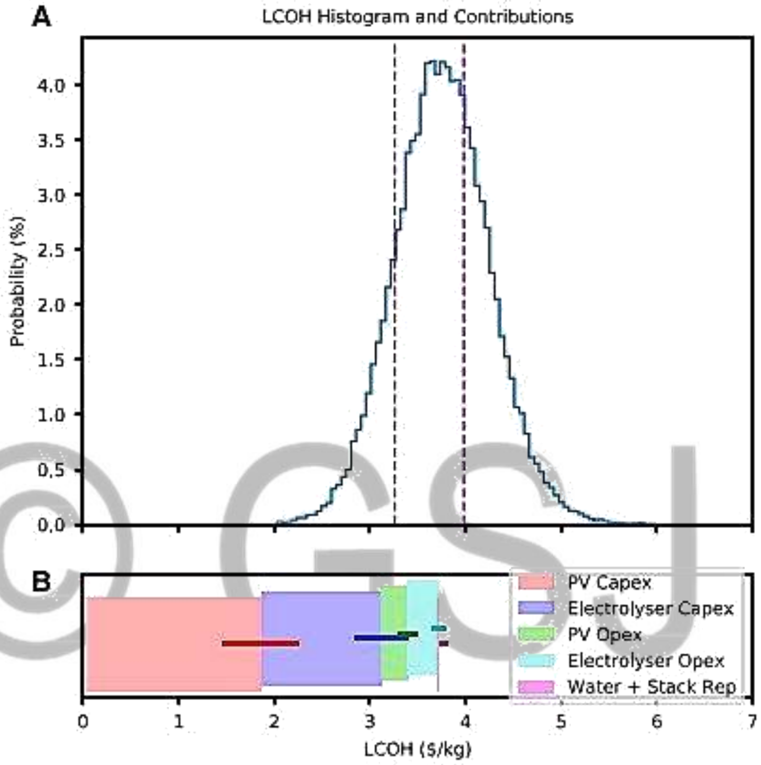


**Figure 10.** Results of Hydrogen Cost equalization (LCOH)

**(A)** LCOH histogram and breakdown for the Townsville base case. The purple lines indicate the estimated range for grid-connected electrolysis in the National Hydrogen Roadmap 6 (above).

**(B)** The bars in the breakdown graph represent the 10th and 90th percentiles for each component (bottom)

It was bred using fossil fuels (2.50 USD/kg). However, some countries have set goals for themselves Import environmentally friendly hydrogen (5-10 million tons of zero-carbon hydrogen to 2050 at the discretion of Japan), so that the market for environmentally friendly hydrogen can provide an increase in price. Assuming that these targets reflect real market demand, the estimated costs in this study may be low enough to justify launching pilot plants in 2020 for To support the growth of the environmentally friendly hydrogen industry. After the launch, the costs will be .They are expected to be further reduced by economies of scale and technological advancements. Developments that expand market opportunities. This idea of creation .The hydrogen export route is already being studied in some countries, such as

Australia with its national hydrogen strategy, Germany's national hydrogen strategy , Japan's basic hydrogen strategy. If distributed hydrogen production can compete with its network-connected counterpart, this allows both production near the place of use or export, and implementation in areas with Ideal energy resources that may not have a suitable network connection for hydrogen production .Development of this model for quick installation of blinds Real-world weather data will also help show whether an object is economically feasible. Distributed hydrogen production.

Next, we study the main factors affecting the LOCH (fig. 10.B) he specified that the capital costs of both the electrolyzer and the photovoltaic installation are the most significant, where the photovoltaic component is higher due to its large size compared to the electrolyzer. The contribution of capital costs to the Public Health Commission varies greatly due to its sensitivity to economies of scale due to the size of the system (discussed below). Such a high dependence on capital expenditures is not surprising, because capital expenditures have been a significant barrier in the market for renewable energy sources. As in many other studies, it can be seen here that the cost of water is negligible, despite the possible shortage and the large cost range used for desalination. However, this does not mean that the use of water can be neglected, since water must still be available in this place, even if it is desalinated sea water.

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