# A Case Study: Samoa

## Tanoa Tusitala Dateline Resort

# The German New Zealand Chamber of Commerce

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# A Word from our CEO

Dear Reader,

The GNZCC's long-held focus has been on delivering projects with an emphasis on energy and climate change; this has been reflected in our projects in New Zealand. Observing the current situation in the Pacific region, the GNZCC has taken a step in a new direction as it enters a new market and builds new relationships with the Pacific Islands. We look forward to building a collaborative and innovative relationship with stakeholders in the Pacific Islands.

Yours sincerely,

Monique Surges, GNZCC CEO

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# A Case Study:

# Samoa – Tanoa Tusitala Dateline Resort

As part of this environmental analysis, the techno-economic feasibility study considers hydrogen as a storage technology. Economic factors such as the levelized cost of electricity, capital costs, and the payback of the investment (break-even point) are also considered. Other relevant metrics include the shares of renewable energy sources, surplus electricity produced, and CO2 emissions.

The scenarios and analyses of the case studies created by using a Multi-Vector Simulation software (MVS) show that energy systems based entirely on renewable, as well as hydrogen and fuel cell technologies, promise substantial cost reductions and emission savings in most cases. The information on the respective conditions and the results of this study, collected by the German Chamber of Commerce and analysed by the Reiner Lemoine Institute, demonstrate the possibilities and economic benefits of integrating green hydrogen and fuel cell technology into the decentralized energy supply of island nations. The project was funded by the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV).

The Tanoa Tusitala Dateline Resort in Apia on Upolu (one of the two main islands of Samoa) is a four-star resort connected to the power grid and equipped with a backup diesel generator that operates during occasional power outages (1-3 hours per month). This section will first introduce all the important input parameters for this case study, followed by a brief overview of the key results from the energy system modelling for the resort.

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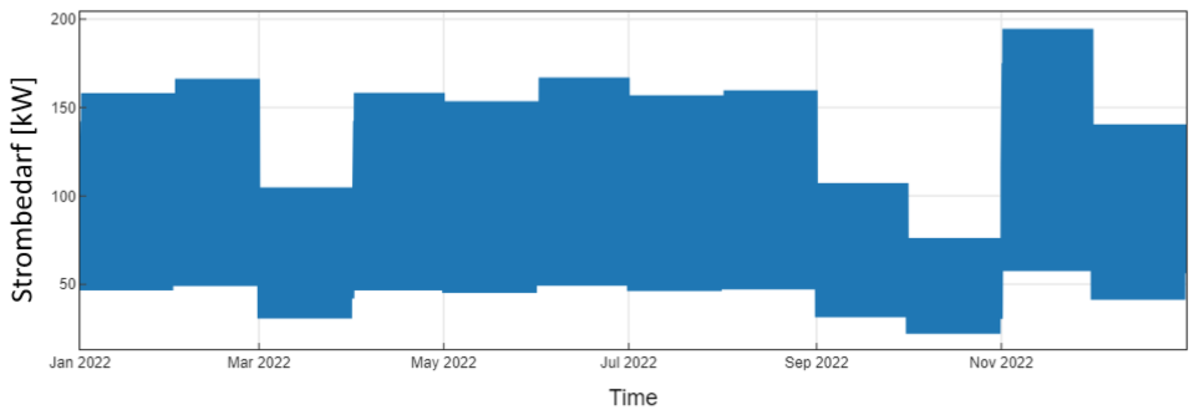
# 1. Electricity Consumption

## 1.1. Tanoa Tusitala Dateline Resort

The load estimation for the Tanoa Tusitala Dateline Resort is based on a monthly electricity bill provided by the resort for a period of one year. Based on this, a potential load profile was simulated assuming three peak times per day (breakfast, lunch, and dinner). The following illustration visualizes the monthly fluctuations in the resort's electricity consumption.

*Illustration 1 Annual Load Profile for the Tanoa Tusitala Dateline Resort*




The key demand characteristics are listed in the table below.

*Illustration 2 Load Demand Tanoa Tusitala Dateline Resort*

| Parameter | Unit | Value |
|---|---|---|
| Peak Load | kW | 195 |
| Average Consumption | kW | 94 |
| Annual Consumption | kWh | 819.444 |

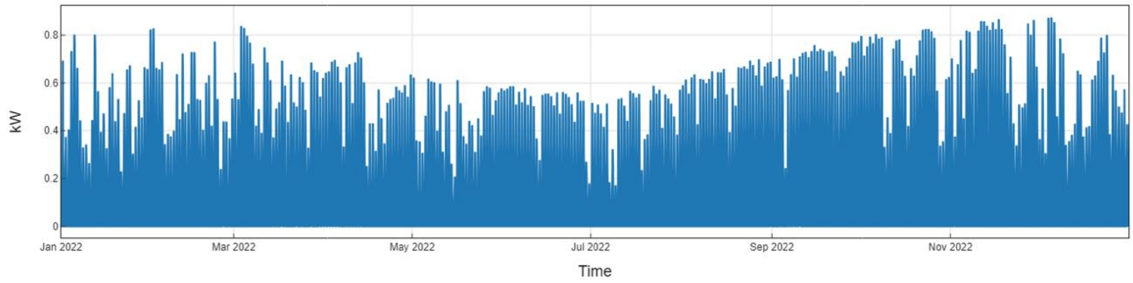
Solar Potential The online tool "Renewables.ninja" was used to calculate the potential hourly electricity generation from PV installations at the site of the Tanoa Tusitala Dateline Resort. The tool takes into account weather information and data, especially solar radiation at specific locations, and converts it into electricity generation using the GSEE model (Global Solar Energy Estimator) (Pfenninger and Staffell, 2016). The selected coordinates correspond to the location of the resort, and the optimal tilt and azimuth angles have been calculated based on these coordinates. They are listed in the table below.

*Illustration 3 Solar Potential Tanoa Tusitala Dateline Resort*

| | |
|---|---|
| Coordinates (Lat., Long.) | -13.827496509496823, - 171.77341280421797 |
| Tilt Angle | 16,1 ° |
| Azimuth Angle | 0 ° (geographic North) |

The following illustration shows the specific PV potential over the course of a year. The annual potential is 1,489 kWh/kWp, with peak production occurring in the winter months and reaching up to 0.87 kW/kWp.

*Illustration 4 Annual Solar Potential for the Tanoa Tusitala Dateline Resort*




Site-specific Input Parameters The important site-specific input parameters for calculating the scenarios are summarized in the following table. The details are based on information provided by the resort or obtained from online research. Additionally, it is important to consider that the resort regularly experiences power outages (about once per month) lasting 1-3 hours, which are bridged with the resort's own diesel generator.

*Illustration 5 Input Parameters Tanoa Tusitala Dateline Resort*

| Parameter | Einheit | Wert | Quelle |
|---|---|---|---|
| Weighted average cost of capital (WACC) | % | 9,22 | ADB, verified by Resort |
| Electricity Price | EUR/kWh | 0,18 | Billing provided by resort |
| Diesel Price | EUR/l | 1,01 | Billing provided by resort |
| Installierter Dieselgenerator | kW | 62,5 | Photos provided by resort |

# 2. Summary of Results

Currently, the Tanoa Tusitala Dateline Resort would not benefit from the use of hydrogen technology. However, the current electricity price (considering power outages and their bridging with the diesel generator) could be reduced by 13% if the resort were to install PV and battery storage to partially replace the generator. After about 7 years, this investment would pay off (break-even point). Should the electricity price in Samoa increase or the investment costs for hydrogen technology decrease, the application of hydrogen technology would also become economically viable for the Tanoa Tusitala Dateline Resort. Additionally, in efforts to achieve a 100% renewable energy supply, hydrogen technology would be economically advisable as a complement to battery storage.

The results for three calculated scenarios are summarized below. The following table initially lists the energy system components and their capacities for each scenario.

*Illustration 6 Evaluation Tanoa Tusitala Dateline Resort*

| Component (Unit)/ Scenario | Dieselgenera-tor (kW) | PV (kWp) | Battery Storage (kWh) | Electrolyzer (kW) | Fuel Cell (kW) | Hydrogen Storage (kg $H_2$) | Electricity (Peak Load) (kW) |
|---|---|---|---|---|---|---|---|
| **Status quo** | 62,5 | - | - | - | - | - | 195 |
| **Cost Minimization** | 57 | 232 | 6 | 31 | 6 | 13 | 195 |
| **100 % RE (PV, $H_2$)** | - | 1.617 | - | 656 | 195 | 500 | - |
| **100 % RE (PV, Bat, $H_2$)** | - | 1.166 | 1.680 | 230 | 51 | 427 | - |

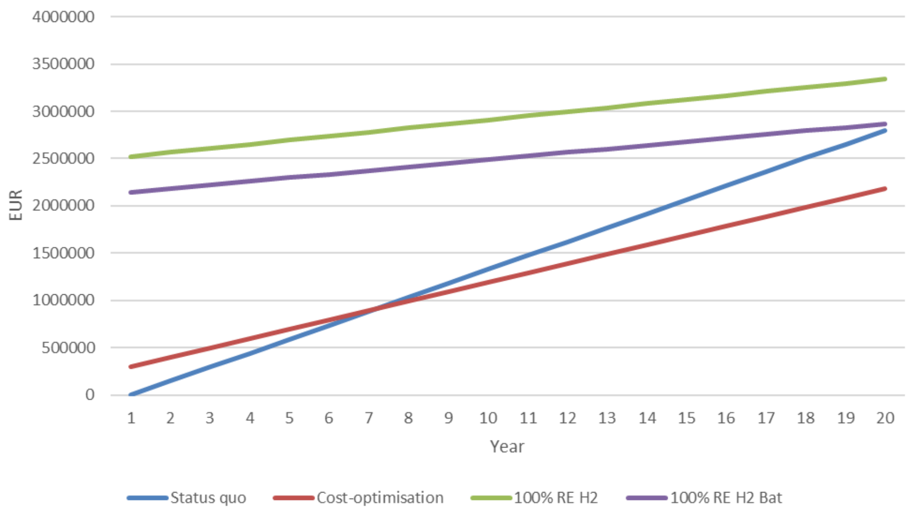
In addition to design parameters, economic indicators such as the levelized cost of electricity, total investment costs, and initial investment costs are important in the analysis of the various scenarios. Also relevant are metrics such as the share of renewable energy, surplus electricity, and CO2 emissions. Another important indicator is the break-even point, which compares the status quo with the investment costs including operation and maintenance costs of other scenarios to determine how many years it takes for the initial investments to pay off. These parameters are summarized in the following table, and Illustration 7 visualizes the calculation of the break-even point.

*Illustration 7 Scenario Parameters Tanoa Tusitala Dateline Resort*

| Metric (Unit)/ Scenario | LCOE (€/kWh) | RE Share (%) | Net Present Value (NPV) (€) | Initial Investment Costs (€) (€) | Operation /Maintenance Costs (€/year) | Break Even Point (years) | Surplus Electricity (MWh/year) | $CO_2$ Emissions ($kgCO_2eq$/ year) |
|---|---|---|---|---|---|---|---|---|
| **Status quo** | 0,185 | 0 | 1.360.702 | 0 | 147.333 | - | 0 | 170.654 |
| **Cost Minimization** | 0,161 | 39 | 1.188.626 | 294.776 | 99.286 | 7 | 50 | 110.969 |
| **100 % RE (PV, $H_2$)** | 0,381 | 100 | 2.807.069 | 2.522.812 | 42.934 | - | 738 | 0 |
| **100 % RE (PV, Bat, $H_2$)** | 0,345 | 100 | 2.538.416 | 2.144.002 | 38.186 | - | 421 | 0 |

The levelized cost of electricity for this case study ranges from 0.16 EUR/kWh to 0.38 EUR/kWh. Only the cost-minimizing scenario reduces the levelized cost of electricity compared to the status quo (by 13%). Both 100% renewable energy scenarios install hydrogen capacities but show significantly increased electricity costs compared to the current electricity supply. No break-even point is reached in these two scenarios, meaning the investment costs for a 100% renewable energy supply do not amortize compared to grid electricity supply under current prices. In the cost-minimizing scenario, the break-even point is reached after about 7 years (as visualized in the following illustration).

*Illustration 8 Visualization of the Calculation of the Break-Even Point*

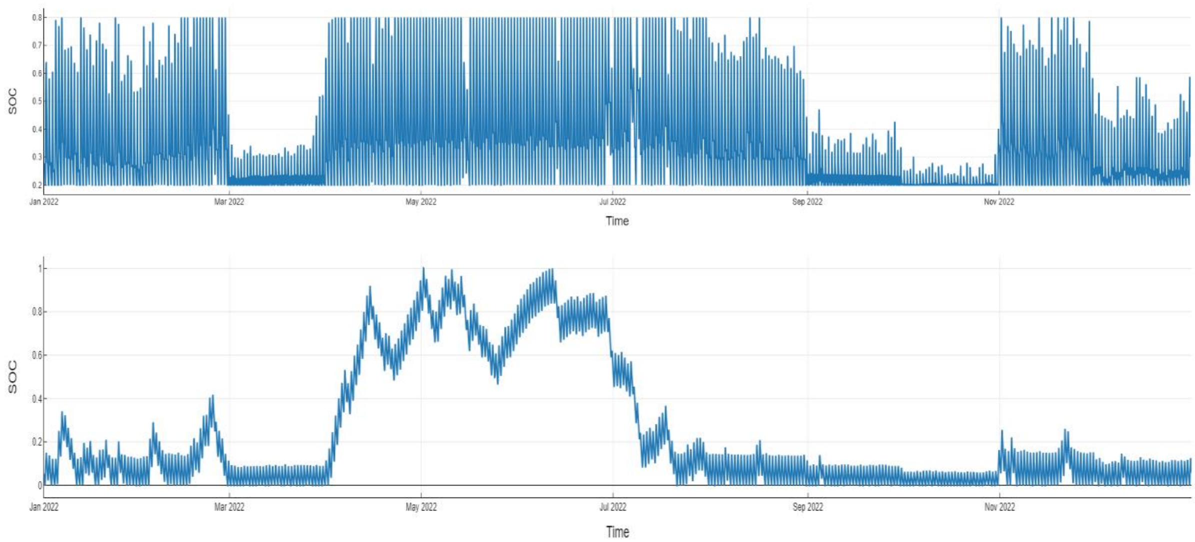


Compared to the status quo, $CO_2$ emissions can be slightly reduced in the cost-minimized scenario. Surplus electricity is generated, which could potentially be used elsewhere (grid feed-in under appropriate regulations or operation of a seawater desalination plant). For hydrogen production, this case study assumes a water requirement of 9 litres per kilogram of hydrogen produced, resulting in a water amount of about 101,070 litres (approximately 277 litres per day) in the 100% renewable energy scenario (PV, battery storage, and hydrogen technology) and for 100% renewable based on PV and hydrogen technology 208,530 litres per year (approximately 571 litres per day). These Illustrations refer again to a 'worst-case' scenario, and ideally, the hydrogen system remains a closed cycle.

Looking at the shares of individual system components in the cost distribution (annuities) for the cost-minimizing scenario, it is evident that the battery storage represents the largest cost item (71%), followed by the hydrogen storage (23%). The hydrogen storage has significantly higher costs than the electrolyser and the fuel cell, as hydrogen is stored long-term, and the storage must therefore be sized accordingly.

To analyse and compare the different operational characteristics and functions of the two storage technologies (battery and hydrogen) more precisely, the following illustration shows the state of charge over a year. While the battery storage (top) shows strong daily fluctuations (amplitudes) and almost daily deep discharge states, the hydrogen storage is less deeply discharged throughout the day but shows strong changes over the course of the year. Especially between May and July, the hydrogen is re-electrified into the system, as solar radiation is lower at this time, and the battery storage more frequently reaches critical charge states. In this case study, hydrogen storage thus mainly serves to balance seasonal fluctuations in solar potential in this scenario.

*Illustration 9 Visualization of the State of Charge (SOC) of the Battery Storage (top) and the Hydrogen Storage (bottom) for the 100% Renewable Energy Scenario (PV, Battery, Hydrogen) Over a Year*



# 3.Sensitivity Analysis

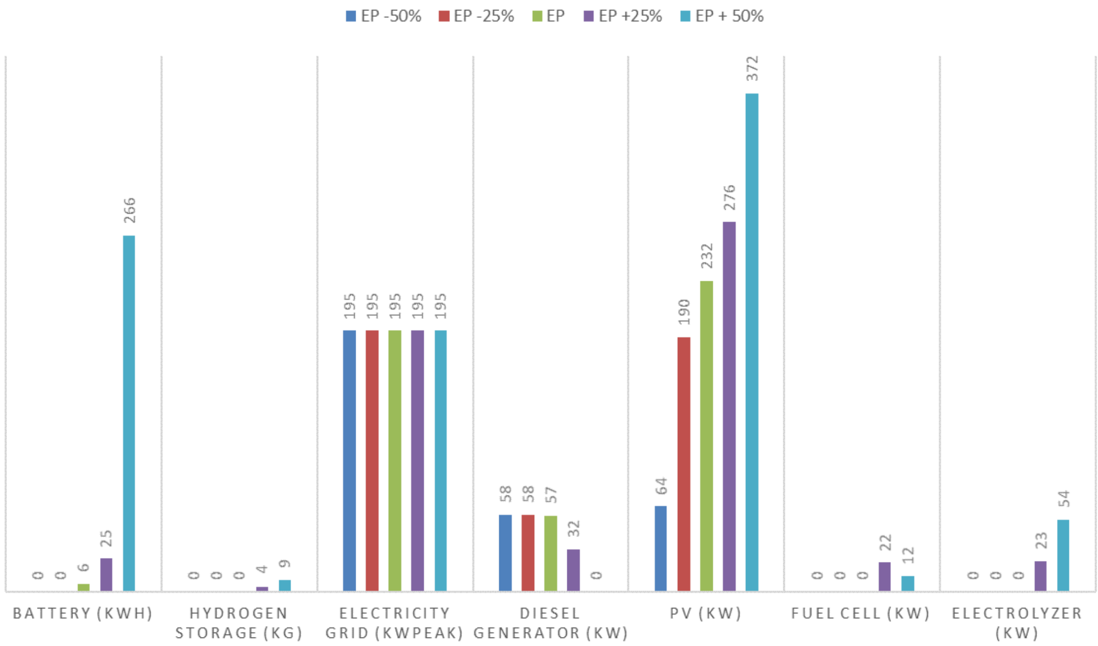
## 3.1. Electricity Price

First, the influence of the electricity price on the simulation results was examined. With an electricity price of 0.178 EUR/kWh for this case study in Samoa, the following changes in electricity prices for the various sensitivity cases (electricity prices 25% and 50% above or below the current level) occur:

- +50% => 0.22 EUR/kWh
- +25% => 0.27 EUR/kWh
- Status quo => 0.178 EUR/kWh
- -25% => 0.13 EUR/kWh
- -50% => 0.09 EUR/kWh

Running the simulation in the MVS for the cost-minimizing scenario, the results visualized in the following graphic are obtained. The capacities of the respective system components are shown, with the reference scenario (cost minimization) displayed in green for comparison.

*Illustration 10 Optimized Capacities of Individual Technologies at Electricity Price Fluctuations*

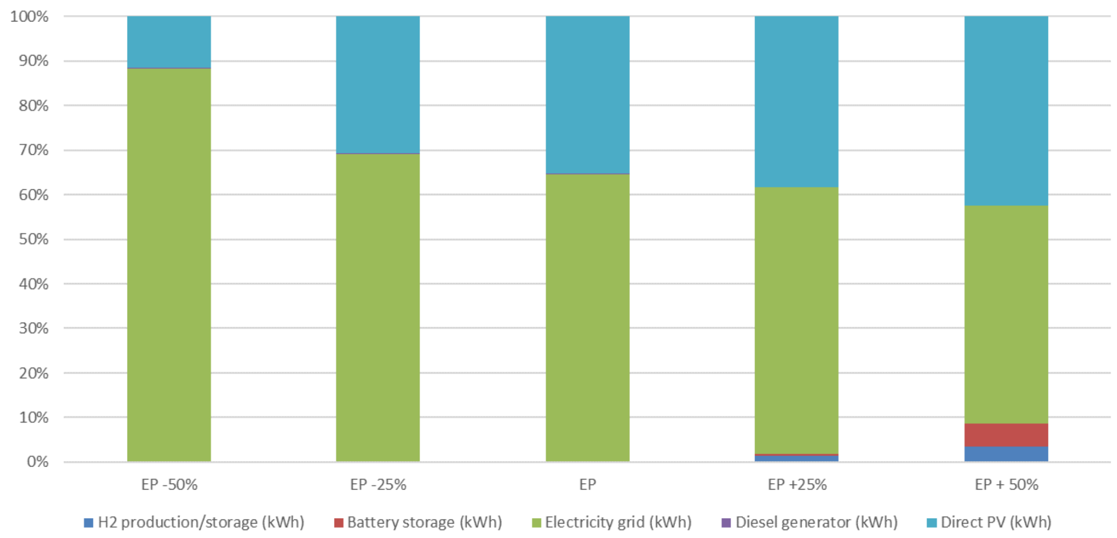



The greatest changes in capacities are seen in the PV and battery storage components. With rising electricity prices (EP), their capacities increase significantly, while with falling electricity prices, their capacities decrease. With electricity price increases (e.g., by 25%), the energy system is expanded to include hydrogen technology. The peak load is drawn from the grid in all sensitivity cases.

If the electricity price in Samoa decreases, the most economical option for the resort is the installation of a solar plant (64 kW or 190 kW) and the operation of a 58-kW diesel backup generator. Storage technologies are then no longer provided. From an electricity price increase of 50%, more storage technology (especially battery but also hydrogen) as well as significantly more PV capacity is recommended. The share of grid electricity for the four sensitivity cases as well as the reference scenario (EP, cost-minimizing scenario) are visualized in the following illustration. The grid electricity consumption moves analogously to price increases or decreases in public power supply.

The following illustration shows the percentage share of the individual system components in covering the electricity demand. "Direct PV" refers to the PV electricity that is fed directly into the system without being directed to the battery storage or the electrolyser for hydrogen production.

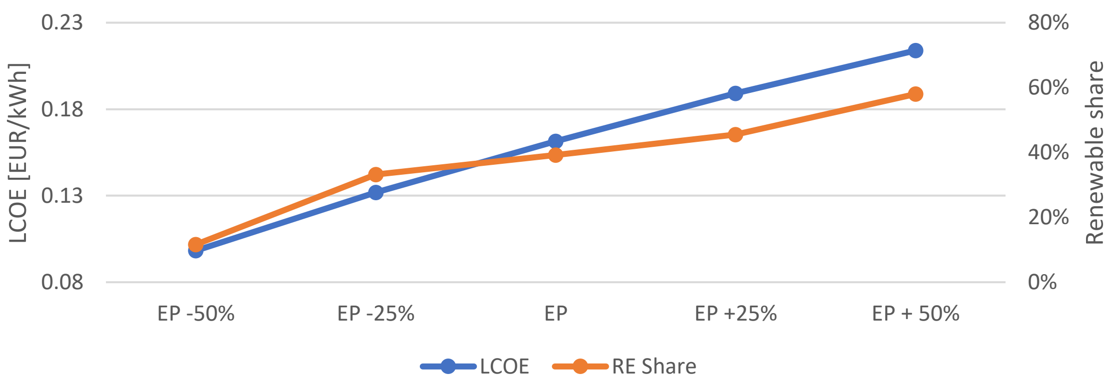
*Illustration 11* Share in Covering Electricity Demand at Electricity Price Fluctuations




***Darstellung 1: Anteil an der Deckung des Strombedarfs bei Strompreisschwankungen***

Here it is also clear that the majority of the electricity demand in all scenarios is supplied from the grid. The higher the electricity price, however, the lower this share and the greater the share of direct PV electricity generation (larger PV system). Storage technologies are only used in cases of electricity price increases of >25% and play only marginal roles in covering the electricity demand even in these cases.
The last illustration of this sensitivity analysis visualizes the development of the levelized cost of electricity and the share of renewable energy in the system.

*Illustration 12 Development of the Levelized Cost of Electricity and the Share of Renewable Energy at Electricity Price Fluctuations*



The levelized cost of electricity fluctuates between 0.10 - 0.21 EUR/kWh (linear increase in LCOE with electricity price). The share of renewable energy in the system moves in the range of 12% - 58% (relevance increases with higher electricity prices) and thus comparatively low.

**Hydrogen Technology Investment**

Costs Sensitivities regarding fluctuations in the investment costs of hydrogen technology were also calculated with assumed increases and decreases of 25% and 50%. This results in the following changes in CAPEX costs:

**Hydrogen Storage (original price at 350 EUR/kg):**

- +50% => 525 EUR/kg
- +25% => 438 EUR/kg
- -25% => 263 EUR/kg
- -50% => 175 EUR/kg

**Electrolyser (original price at 610 EUR/kW):**

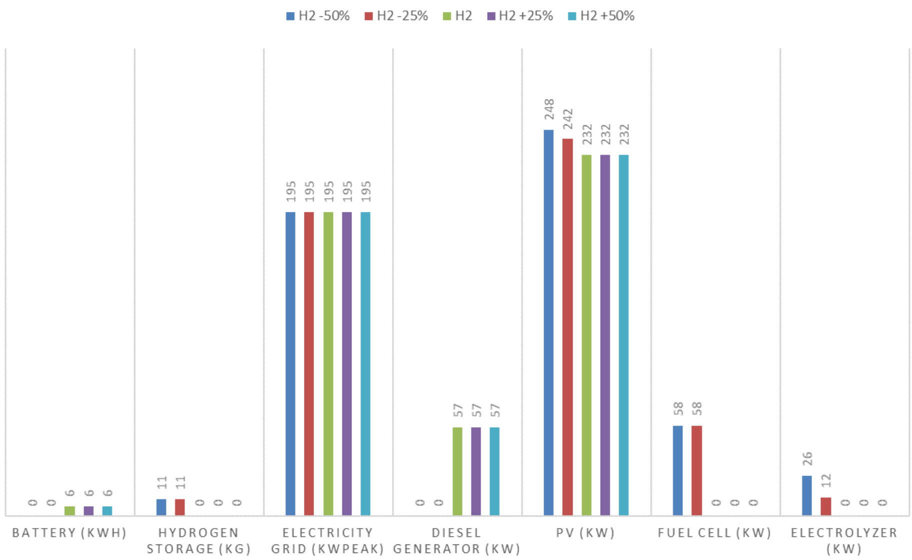
- +50% => 915 EUR/kW
- +25% => 763 EUR/kW
- -25% => 458 EUR/kW
- -50% => 305 EUR/kW

**Fuel Cell (original price at 870 EUR/kW):**

- +50% => 1,305 EUR/kW
- +25% => 1,088 EUR/kW
- -25% => 653 EUR/kW
- -50% => 435 EUR/kW

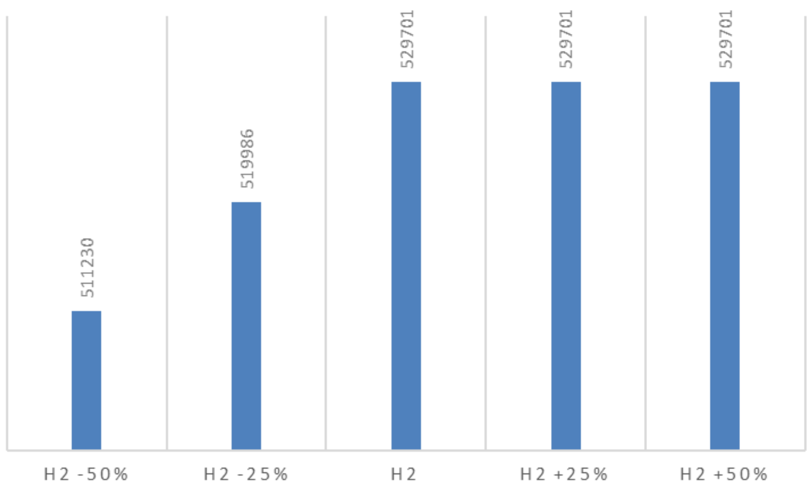
Analogous to the sensitivity analysis of the electricity price, the development of the capacities of the individual system components at fluctuations in the investment costs of the hydrogen components was displayed. Here too, the reference scenario (cost minimization under status quo prices) is displayed in green.

*Illustration 13 Optimized Capacities of Individual Technologies at Fluctuations of Hydrogen Investment Costs*



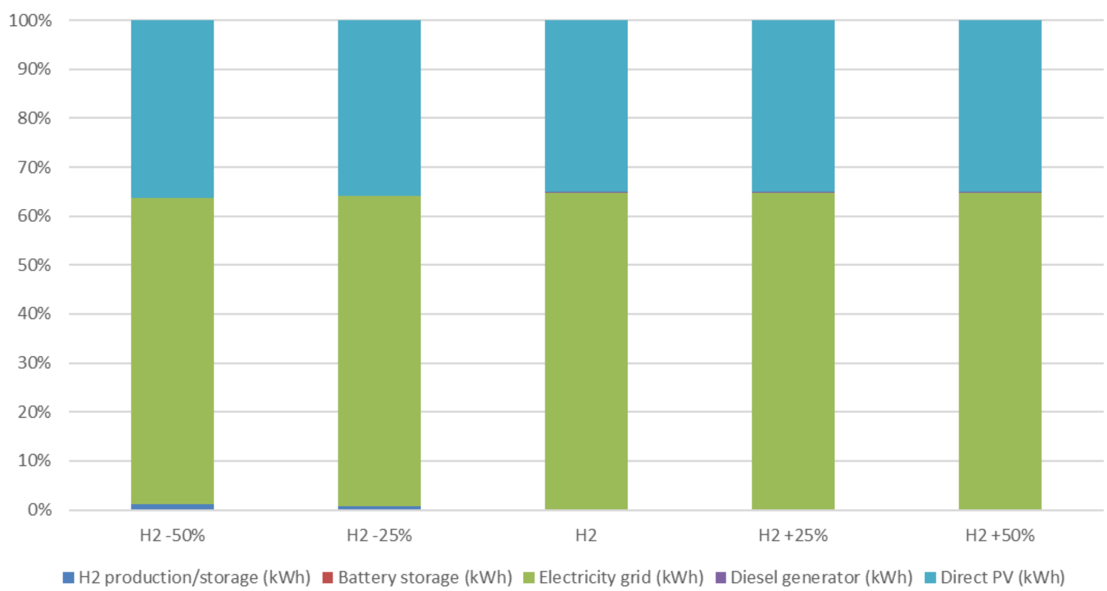
If the prices for hydrogen components decrease by 25% or more, hydrogen technology plays a role in this case study and becomes part of the recommended energy system as a replacement for the battery storage and as a complement to the PV plant and grid electricity supply. Here too, in all sensitivity cases, the peak load is supplied from grid electricity. Now looking at the grid electricity consumption in kWh (following illustration), it is clear that with decreasing component costs of hydrogen technology, the share of grid electricity consumption decreases (increased feeding from intermediate hydrogen re-electrification).

*Illustration 14* Grid Electricity Consumption in kWh for the Calculated Sensitivity Cases (Investment Costs of Hydrogen Components)



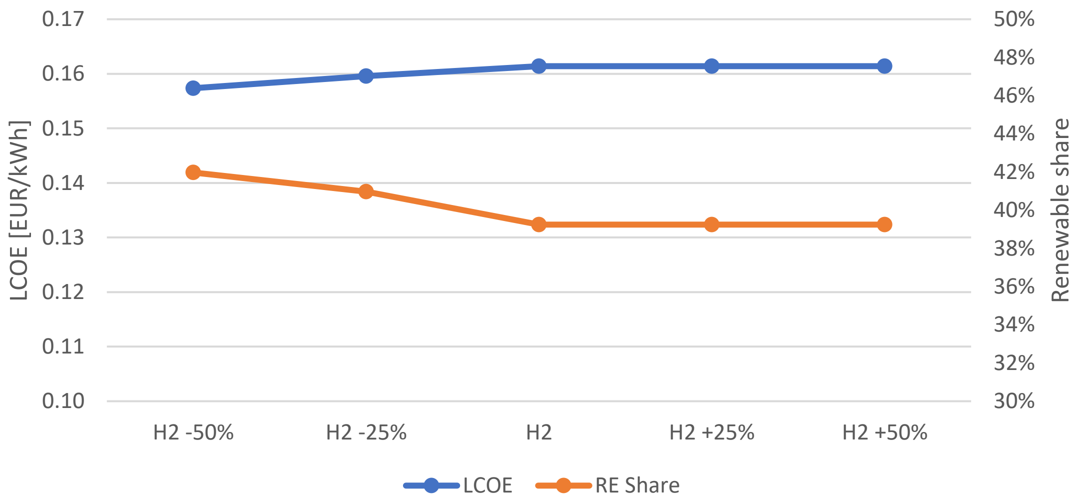

This is also supported by the following illustration. While the share of supply from the power grid slightly decreases with falling hydrogen component costs, the supply from the fuel cell increases.

*Illustration 15 Share in Covering Electricity Demand at Fluctuations of Hydrogen Investment Costs*



The following illustration finally shows the development of the levelized cost of electricity and the share of renewable energy for the sensitivity cases. It is clear that the levelized cost of electricity shows relatively minor fluctuations with rising or falling hydrogen component costs. The share of renewable energy fluctuates between 39% and 42%, and compared to electricity price sensitivities, it is lower. Comparatively, it can be said that fluctuations in electricity prices in this case study have stronger influences on the economy or system component design.

*Illustration 16 Development of the Levelized Cost of Electricity and the Share of Renewable Energy at Fluctuations of Hydrogen Investment Costs*




# 4. Conclusion

The currently most cost-effective solution for the Tanoa Tusitala Dateline Resort on Samoa is the installation of a PV plant and a small battery storage as a complement to grid electricity and the backup diesel generator. This combination could reduce the current electricity costs of the resort by about 13%. Both 100% renewable energy scenarios involve hydrogen technology but would increase electricity costs by about 100% compared to the current system (grid electricity and backup diesel generator). If the electricity tariff increases (e.g., by 25%), the application of hydrogen technology becomes economically viable, and grid electricity consumption is complemented by PV, battery storage, hydrogen technology, and the backup diesel generator. If the costs for hydrogen components decrease (e.g., by 25%), hydrogen technology completely replaces the diesel generator and battery storage in the system.

**Translation Disclaimer**

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