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Smart grid operation while integrating photovoltaic through green hydrogen technology.

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Smart Grid Operation while Integrating Photovoltaic through Green Hydrogen Technology

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Introduction

Environmental pressures coupled with high fossil fuel prices have led to the rapid penetration of electricity generation from Renewable Energy Sources (RES). Because of the rapid RES penetration, the stability of grid energy infrastructures are now being heavily compromised and new solutions must be devised.

A critical grid stability aspect when using RES is managing the mismatch of demand versus generation:

- When there is low load demand for energy, RES could be at their peak generation
- When there is high load demand, RES could be at their lowest generation

Any of the above scenarios can lead to a grid collapse, causing black outs.

Increasing RES penetration, while maintaining stability, can be achieved by utilising Green hydrogen (H2) technologies within a 'smart grid' infrastructure.

In a smart grid H2 set up, any excess in RES generation can be absorbed and stored as hydrogen gas through the use of electrolysis. This stored H2 can then be utilised in Fuel Cells (FC), gas turbines or internal combustion engines to generate power when RES generation is low or not available.

Therefore, H2 can be considered as one of the most important enablers for RES in the world. The greatest challenges facing the uptake of H2 technology as a grid stabiliser solution are the cost reduction and the development of high value use for the hydrogen gas while improving its production efficiency.

This research project has investigated a H2 smart grid setup and demonstrated through both economic and system performance modelling that H2 technology can be used as an enabling technology for increased RES penetration.

Stored H2 produced from RES has many applications:

- **Stabilising the grid**
- **High value, zero carbon fuels**
- **Metallurgy**
- **Oil and Gas refining**
- **Electronics manufacture**

By-product oxygen from H2 electrolysis can also be used:

- **To enhance hydrogen combustion**
- **Aquaculture to breed fish**
- **Industrial process gasses**
- **Metallurgy for welding (in oil and gas industry)**
- **Hospitals and other applications**

The essential elements of a hydrogen technology based energy storage system are shown in figure 1:

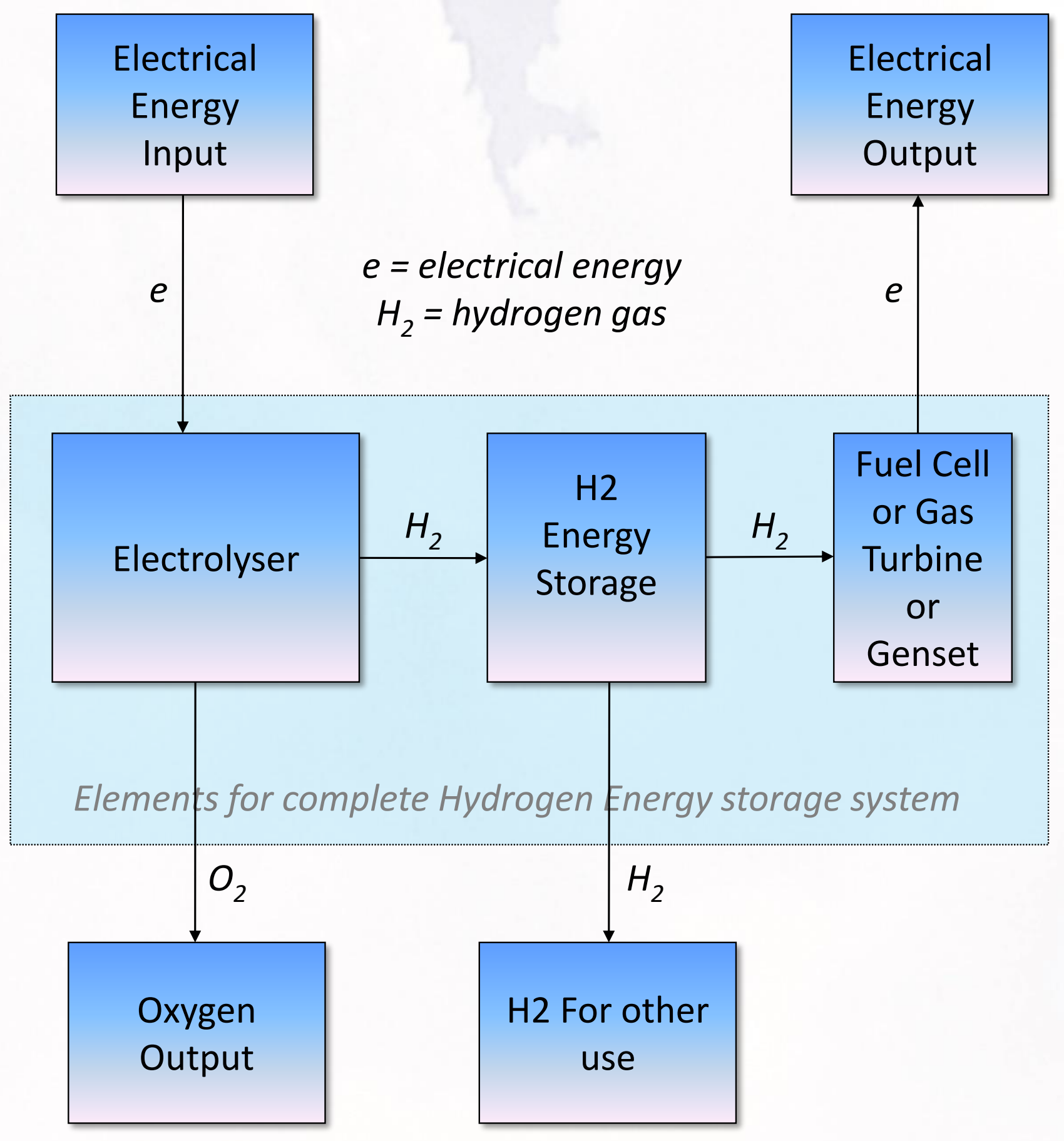


Figure 1: *Elements of a hydrogen energy system*

Economic Modelling

An economic modelling research on hydrogen energy storage systems has shown that H2 offers a much higher level of versatility over conventional energy storage systems. Figure 2 shows how H2 Energy systems has a greater revenue generating potential:

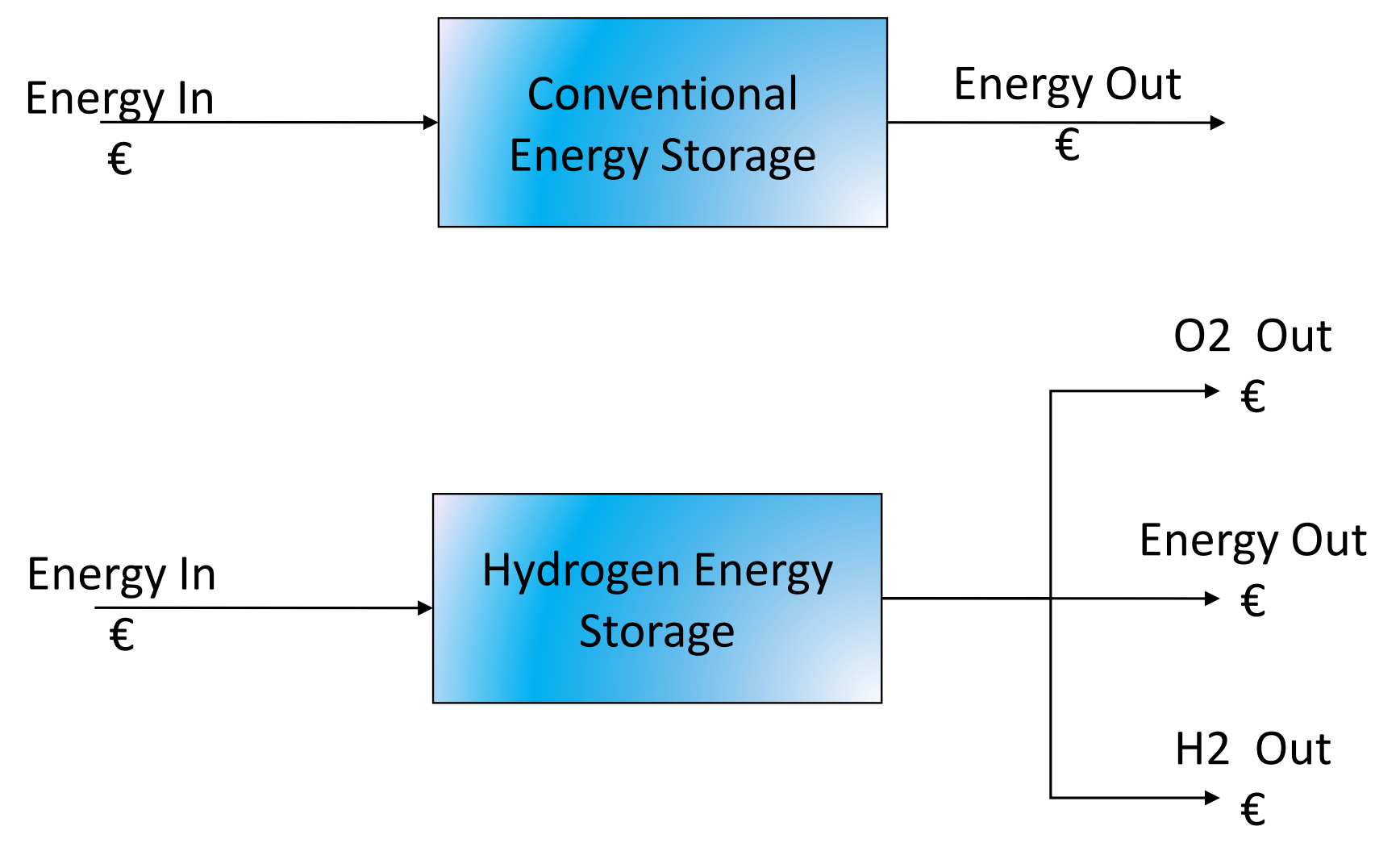


Figure 2: *Versatility offers additional revenue sources.*

Results of the proposed Levelised Storage Cost (LSC) model are presented in figures 3 and 4. The LSC model has been developed to assess the economic performance of the H2 energy storage technology while using real world data of the reference system defined in the "System Performance Modelling" section.

Five LSC scenarios have been modelled in order to define which application has the most favourable return on investment.

Scenario A	100% 02 & H2 sold as gases
Scenario B	100% energy sale through 3MW FC, 100% 02 sold, no H2 sale
Scenario C	50% O2 & H2 gas sold, 50% H2 sold as Energy through a 3MW FC
Scenario D	No FC (no energy sale), No 02 Sold, 100% H2 sold
Scenario E	100% Energy sold (3MW FC), no O2 nor H2 sold

In each scenario, hydrogen storage capacity has been defined as 5MWh pressurised gas storage.

The best return on investment from RES H2 and O2 production system was found to be on selling H2 and O2 as gas (scenario A)

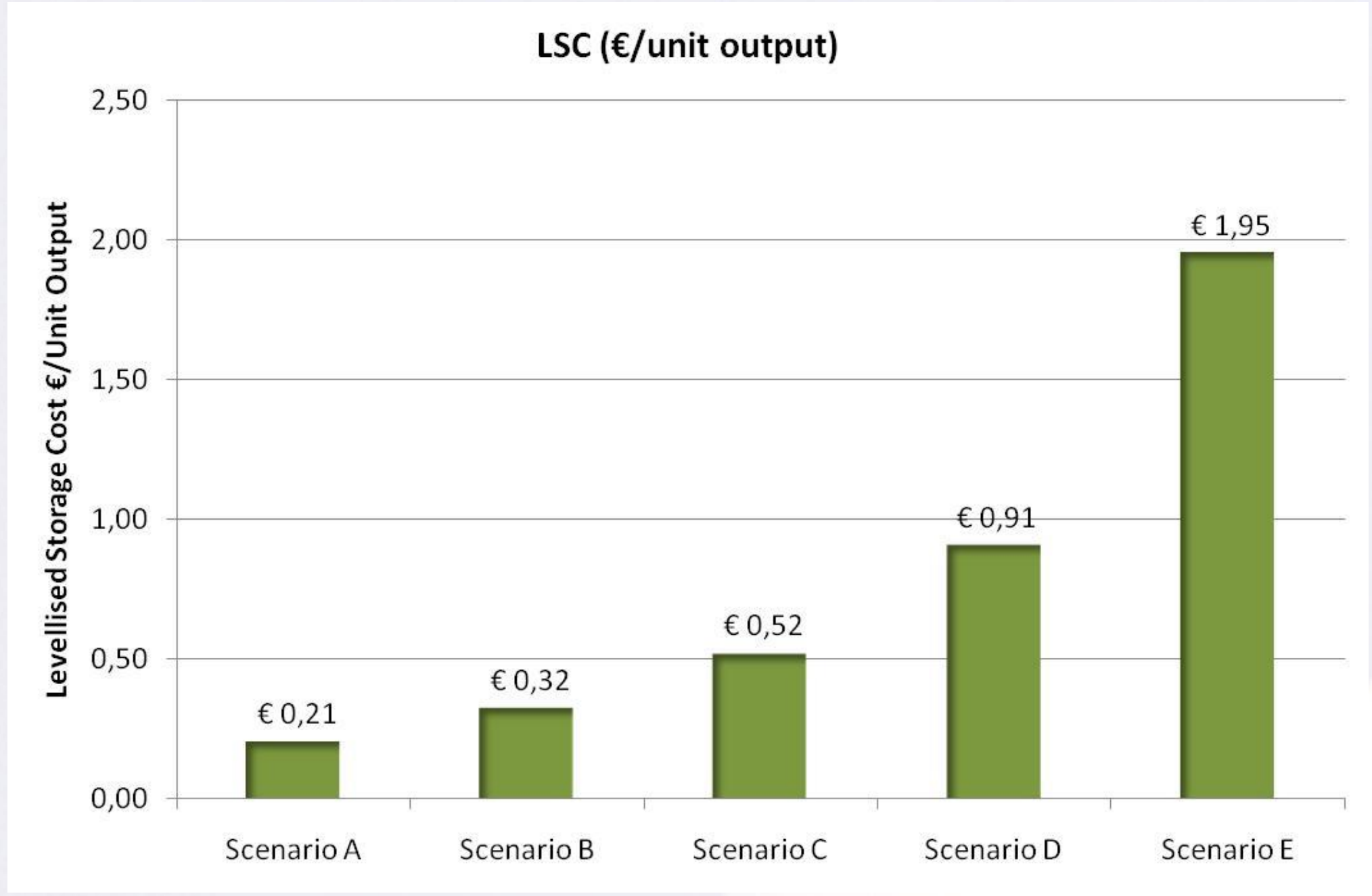


Figure 3: *Levelised output costs for H2 energy storage system.*

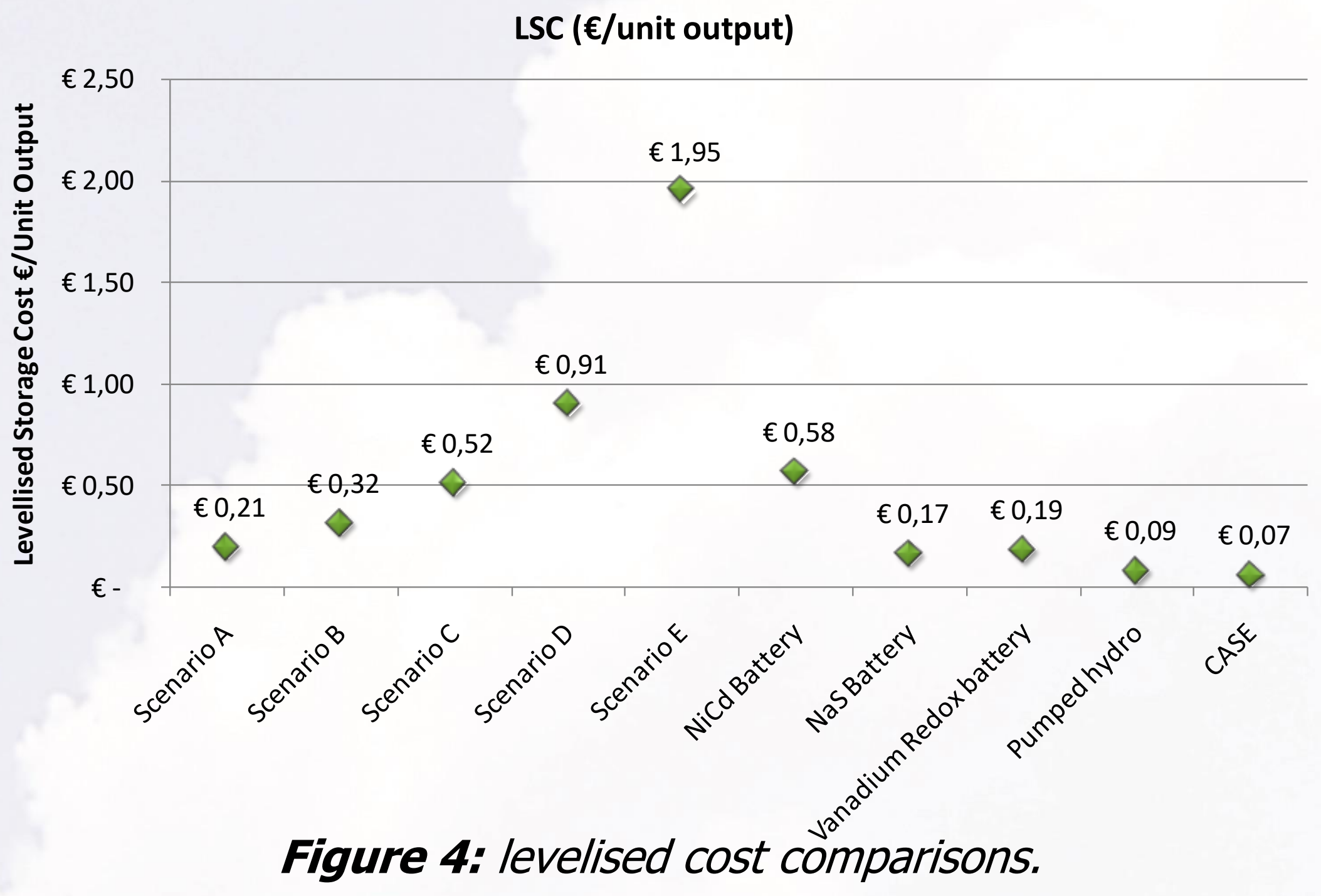


Figure 4: *levelised cost comparisons.*

System Performance Modelling

Hydrogen production and storage models have been developed and verified against 'real-world' data collected from installed and operating systems in the field. The reference system used for verifying the model is a 180 cell, 5.33Nm^3/h 12 bar electrolyser connected to 2400L storage capacity. An outline of the system can be seen in figure 5.

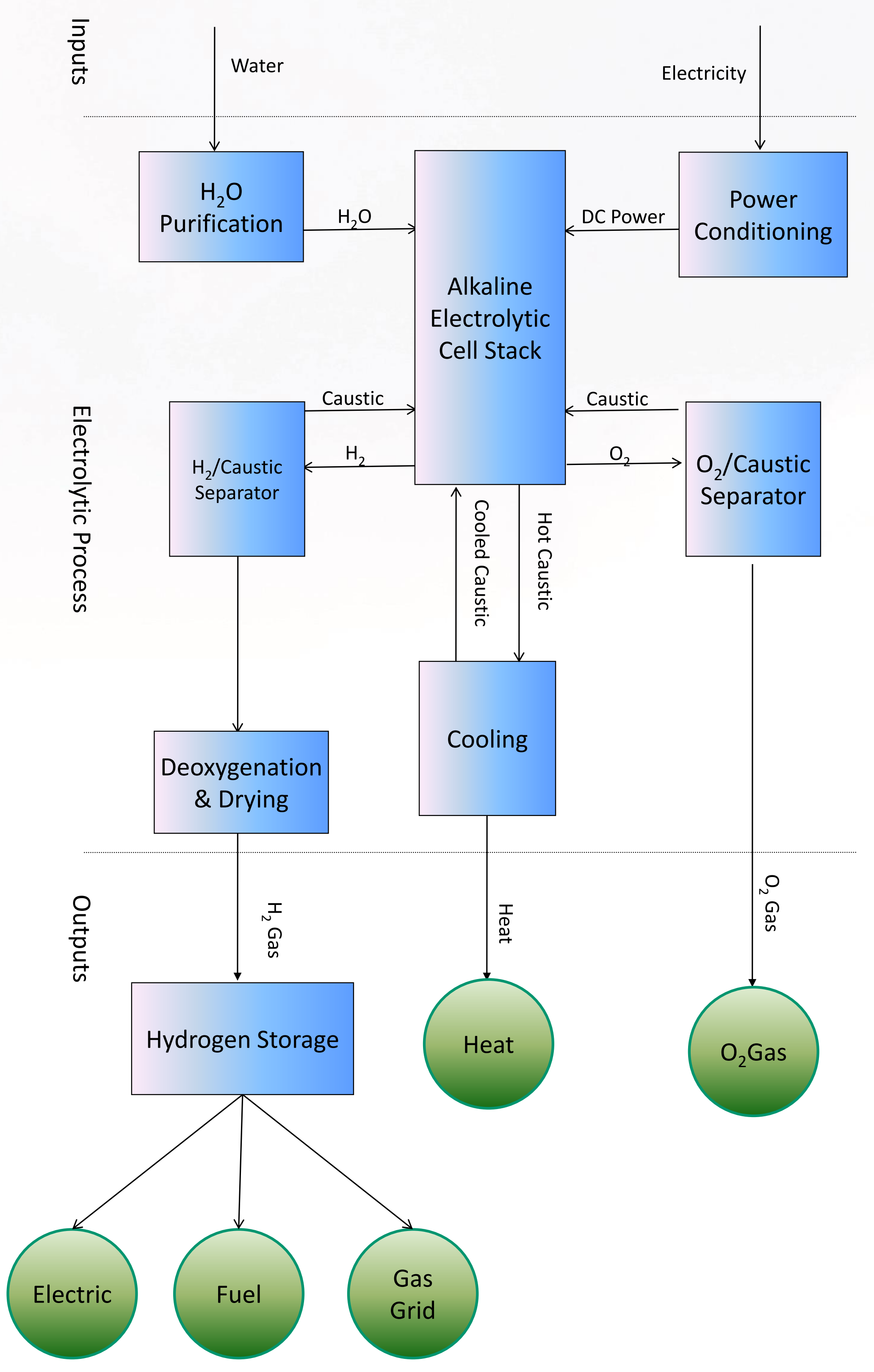


Figure 5: *Developed system model overview.*

Figures 6 and 7 demonstrate that the hydrogen technology developed model provides near 100% identical results to the collected data from the reference real world system. This allows to conquer that the model can be used for simulating real world installations before embarking into expensive capital investment.

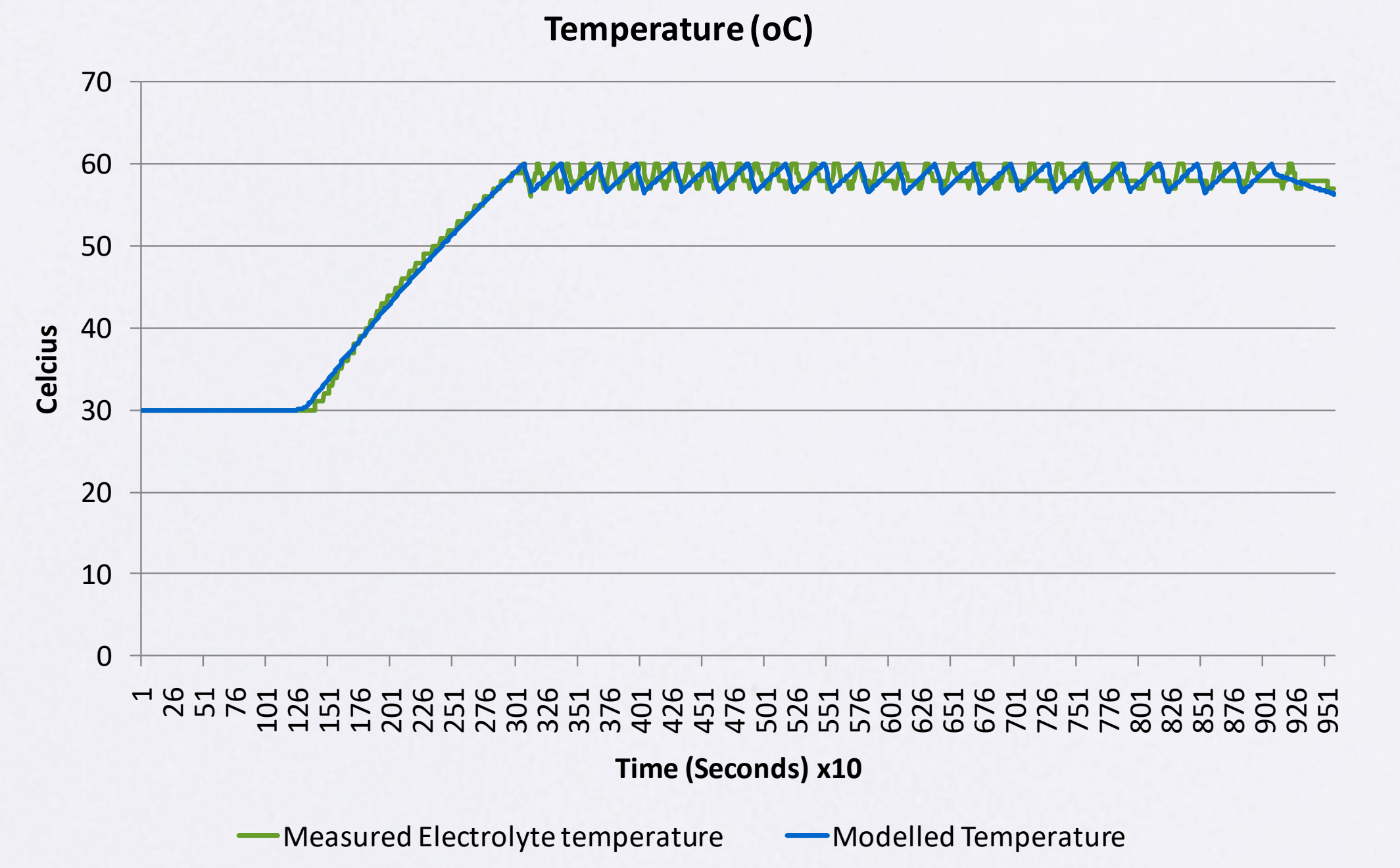


Figure 6: *Thermal comparison*

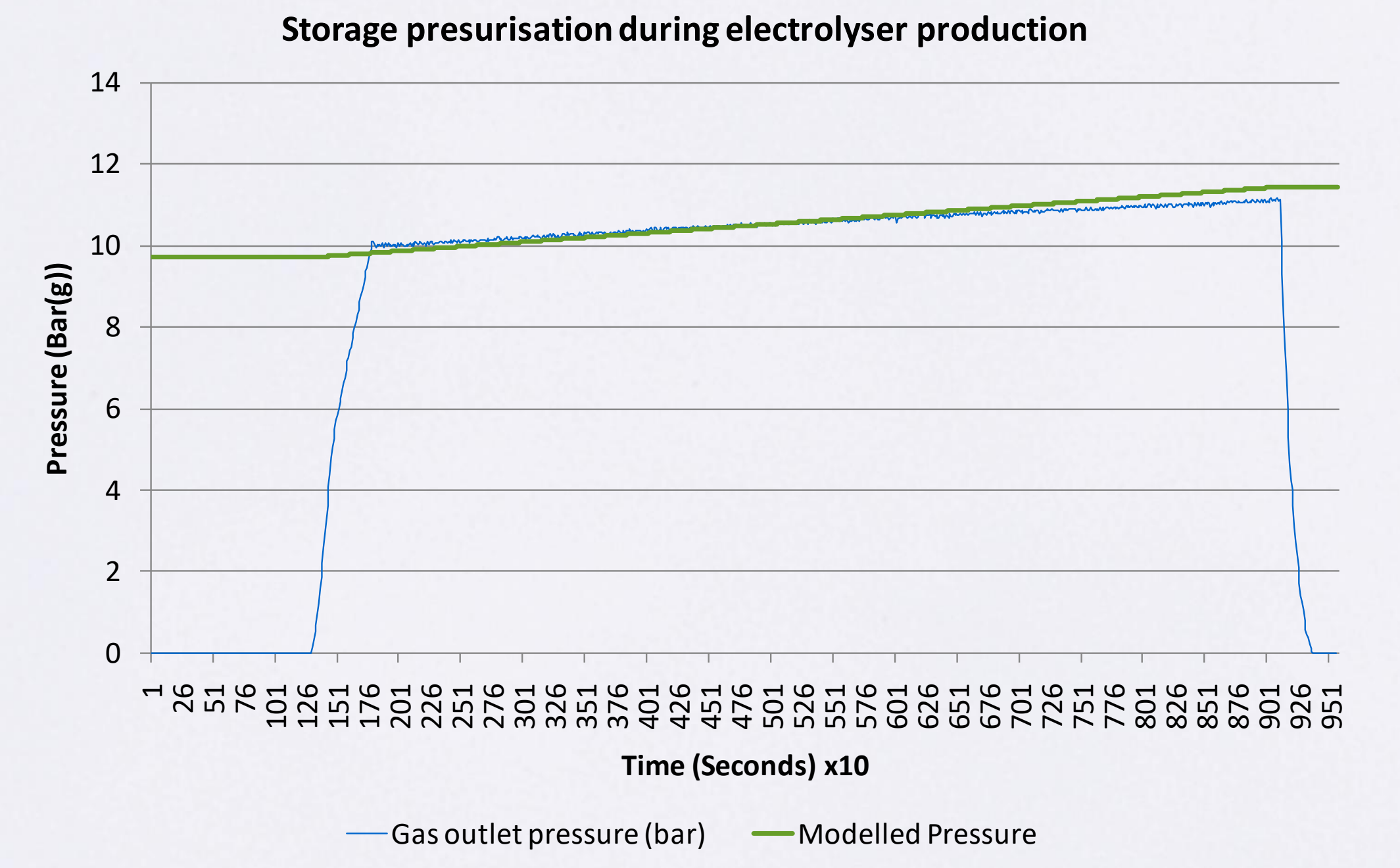


Figure 7: *Pressure comparison*

Case Study Discovery of a gas leak by modelling

Moreover, the developed H2 system model has been then used and compared to data collected from a number of infield systems that did not perform as anticipated. The aim was to determine what was wrong with those systems.

When the models were run and compared to the real-world data, they revealed a possible performance issue due to a hydrogen leak within the installation.

Performance deviation can be seen in figure 8, where pressurised hydrogen storage deviated from the expected profile. The model has revealed a *hydrogen gas* leak of about 10.89g an hour from the system. *This loss equated to a 2.3% reduction in the overall system efficiency.*

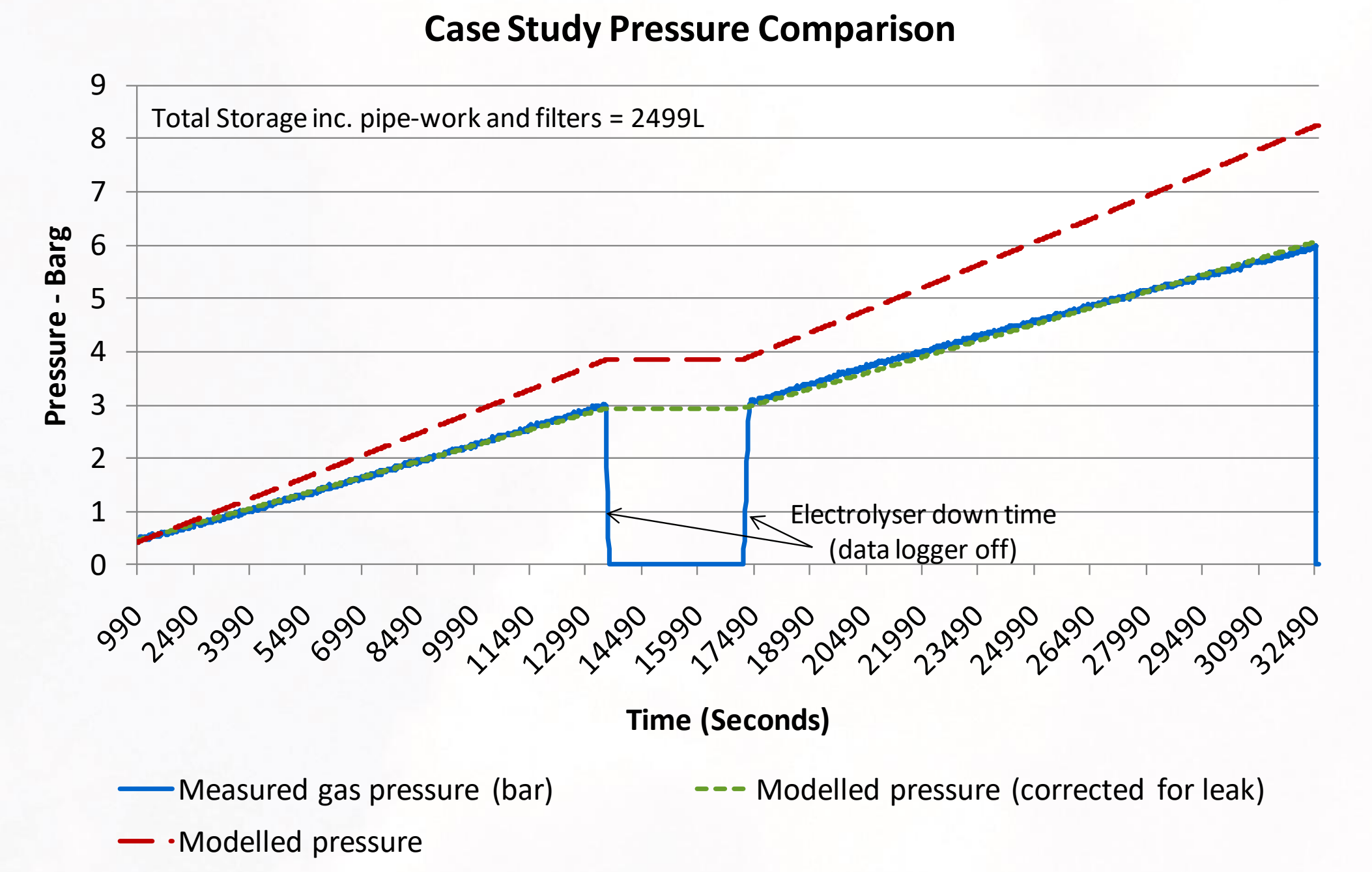
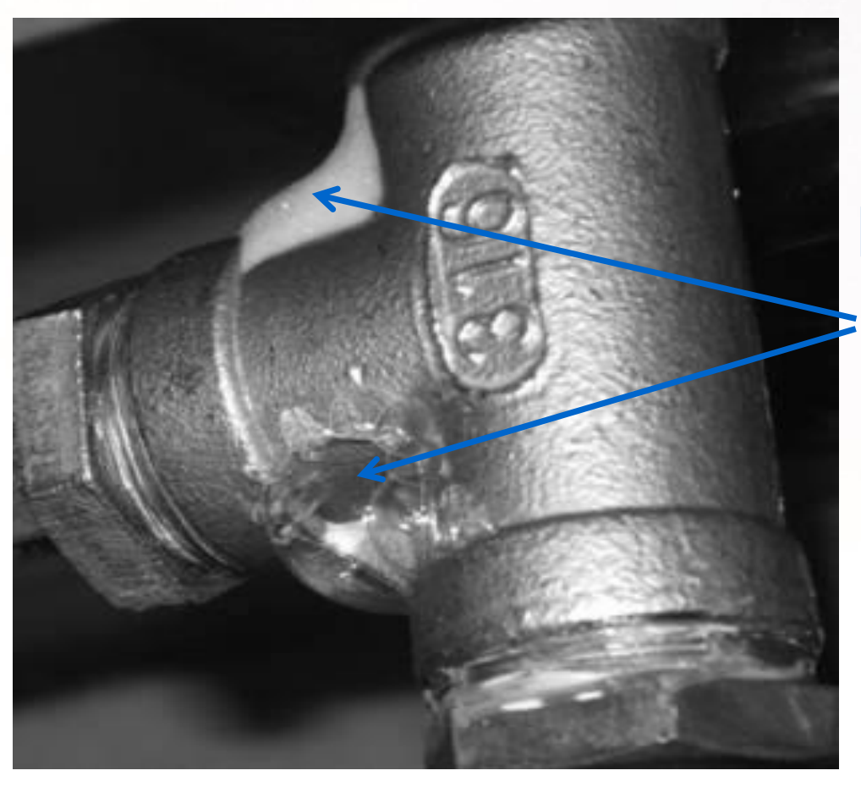


Figure 8: *Model applied to identify system leak*

Based on the above modelling results, a team of technicians has been sent onsite. The onsite investigation revealed a broken pipe fitting causing a leak. This result clearly demonstrates the apparent benefit of the proposed model in identifying the source of the problem and saving the time of onsite investigation.

Figure 9 illustrates the root cause of the system performance deviation, created by a failed gas fitting.



Fitting cracked around top of casting causing H2 leakage.

(See white bubble foam)

Figure 9: *Cause of hydrogen leak*

IMPORTANT - The proposed model and findings of this research can be applied to any other gas or liquid machinery, such as those in the oil and gas industry, to identify a leak and save the time required for onsite visits prior maintenance

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