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# Increasing the penetration of renewables by stabilising the grid through the use of energy storage: fuel cell technologies.

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# Increasing the penetration of renewables by stabilising the grid through the use of energy storage - fuel cell technologies

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## Introduction

Renewable energy represents a small fraction of the total power generation profile in use today. However, recent global climate change policies have lead to significant increases of electricity generation from Renewable Energy Sources (RES).

Within Scotland, ambitious national targets are focused on delivering the equivalent of at least 100% of gross electricity consumption from renewables by 2020. Traditional modelling suggests that the maximum stable renewable energy mix is up to 20% without additional load management and energy storage.

Recent studies concludes that utilisation of renewables is held back by lack of energy storage solutions and identifies early adoption markets in island and 'off grid' scenarios worth €25bn to 2030 globally. [1]

This research suggests a stable renewable penetration into the grid through energy storage solutions through modelling mixed generation electrical energy 'grids' in the presence of a Renewable Hydrogen Energy Storage System (ESS).

## Economic Viability & Energy Storage Capacity Modelling of Renewable $H_2$ ESS:

The economic viability and the Energy Storage capacity of a Renewable Hydrogen ESS, for an existing hydrogen ESS in the Hydrogen office, has been modelled and examined before proposing incorporating them as a solution for stable renewable penetration into the grid.

A levelised storage cost (LSC) economic model has been developed to examine its economic viability and analyse the different possible scenarios for operating a hydrogen ESS, and concluding the most viable scenario. These scenarios are:

A. No energy sale, only 100% 02 and H2 gas sale
B. 100% energy sale via fuel cell, 100% 02 sale, and no H2 sale
C. 50% O2 & H2 gas sale, and 50% H2 sale as Energy via a fuel cell
D. No energy sale, No 02 Sale, only 100% H2 sale
E. 100% Energy sale via fuel cell, no O2 nor H2 sale

Figure 1 shows the results obtained for each scenario described.

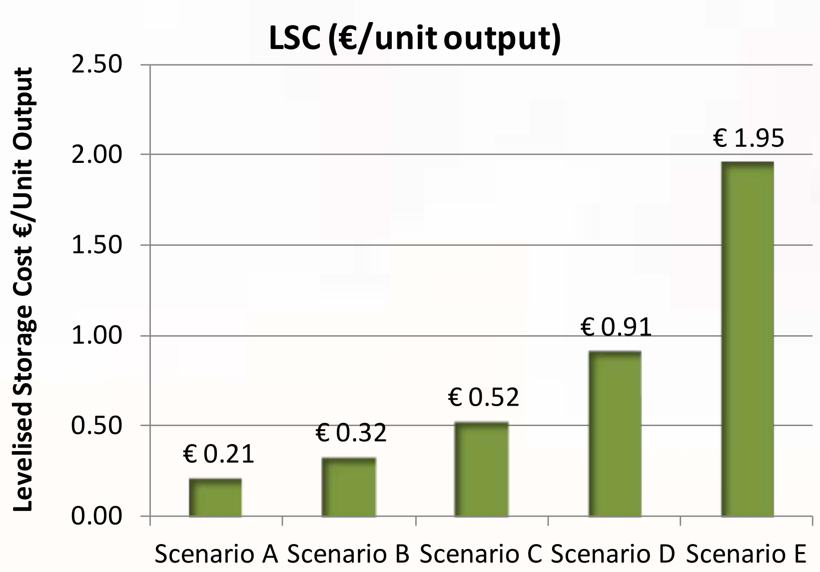


**Fig.1:** LSC cost analysis results for different scenarios

Modelling results in figures 2a and 2b show the effect of increasing user demand on a hydrogen ESS.

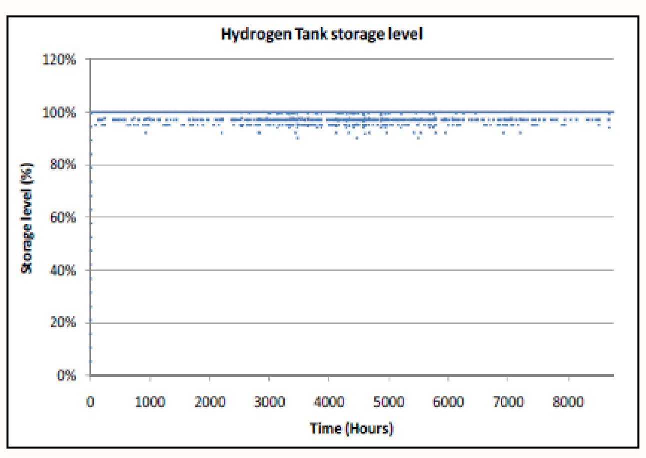


**Fig.2a:** shows initial user demand on hydrogen ESS

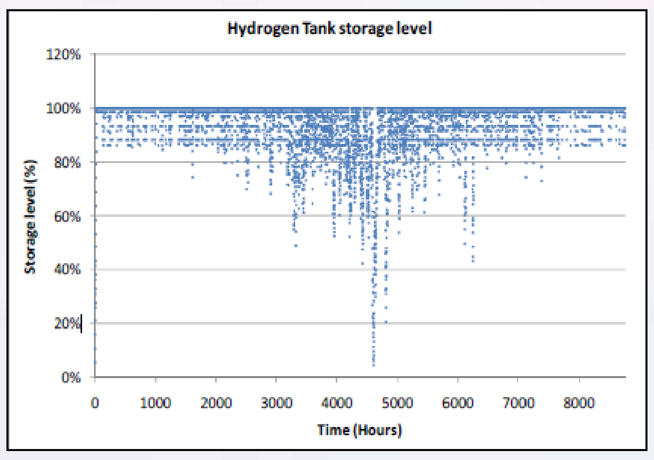


**Fig.2b:** Modelling results show effect of increasing user demand on hydrogen energy storage system

## Proposed Hydrogen ESS

A hydrogen ESS proposed for enabling the projected increase of renewable generation onto the electrical power grid is presented below.

Hydrogen ESS typically comprises of 3 main components for storing energy, these are:

- Electrolyser for converting the excess in renewable energy production and water into hydrogen and oxygen gas
- Hydrogen gas storage tank and compressor
- Fuel cell

Electrolyser performance is first simulated using the Øystein Ulleberg model [2]. This provides performance details of the electrolysis DC voltage and current, electrolysis temperature, hydrogen production rate and efficiency.

Hydrogen storage has been modelled using the ideal gas laws and correction factors [3]: The model profiles the amount of energy stored within the hydrogen storage tanks and will also provide details of the operating pressures and stored hydrogen mass. The model also enables analysis of appropriate storage size for energy demands placed upon it by end users and renewable generation availability.

## Mini-Grid Model

Based on the Island of Eigg energy system, a simplified schematic of a hybrid energy system that incorporates a variety of generation sources has been developed for modelling the impact of hydrogen energy storage. The suggested system is shown in figure 3.

To enable the analysis of the suggested Renewable Hydrogen ESS when used in conjunction with a mixed energy network such as that found in islanded electrical networks and off grid energy systems, models for simulating each of the following components in the mini-grid have to be developed:

- Wind Generation
- Solar PV
- Battery
- Hydrogen ESS
- Diesel
- Hydro

Based on the technical information found in manufacturer's data sheets, each model will simulate the performance of generation. The overall model will then simulate varying user demands and identify the energy system renewable resources and its storage ability in meeting a given load profile

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## Conclusion

The economic viability of incorporating Hydrogen ESS to enable the projected increase of renewable generation onto the electrical power grid has been analysed and different scenarios has been considered to find out that:

- Hydrogen ESS can allow grid balancing while enabling the projected increase in renewable generation.
- It has a financial benefit as it allows utilisation of surplus RE in alternative economic pathways, known as 'sector shifting' (H2 is not only limited to electrical energy production but can be sold with O2 for other purposes).
- The renewable hydrogen ESS has the most economic potential when by-product Oxygen is also sold from the electrolysis process as well.

A simulation model has also been developed to examine the performance & energy storage capacity of a renewable hydrogen ESS.

Models for the items shown in the simplified schematic have also been developed to enable the simulation of island and 'off grid' energy systems while incorporating hydrogen ESS for analysis and automatic sizing.

## References

[1] Cornelius Pieper and Holger Rubel, "Revisiting Energy Storage: There is a business case" , Boston Consulting Group, February 2011

[2] Øystein Ulleberg, "Modeling of advanced alkaline electrolyzers: a system simulation approach", International Journal of Hydrogen Energy 28 (2003) 21 – 33

[3] Eric W. Lemmon et al, "Revised Standardized Equation for Hydrogen Gas Densities for Fuel Consumption Applications", Journal of Research of the National Institute of Standards and Technology, Volume 113, Number 6

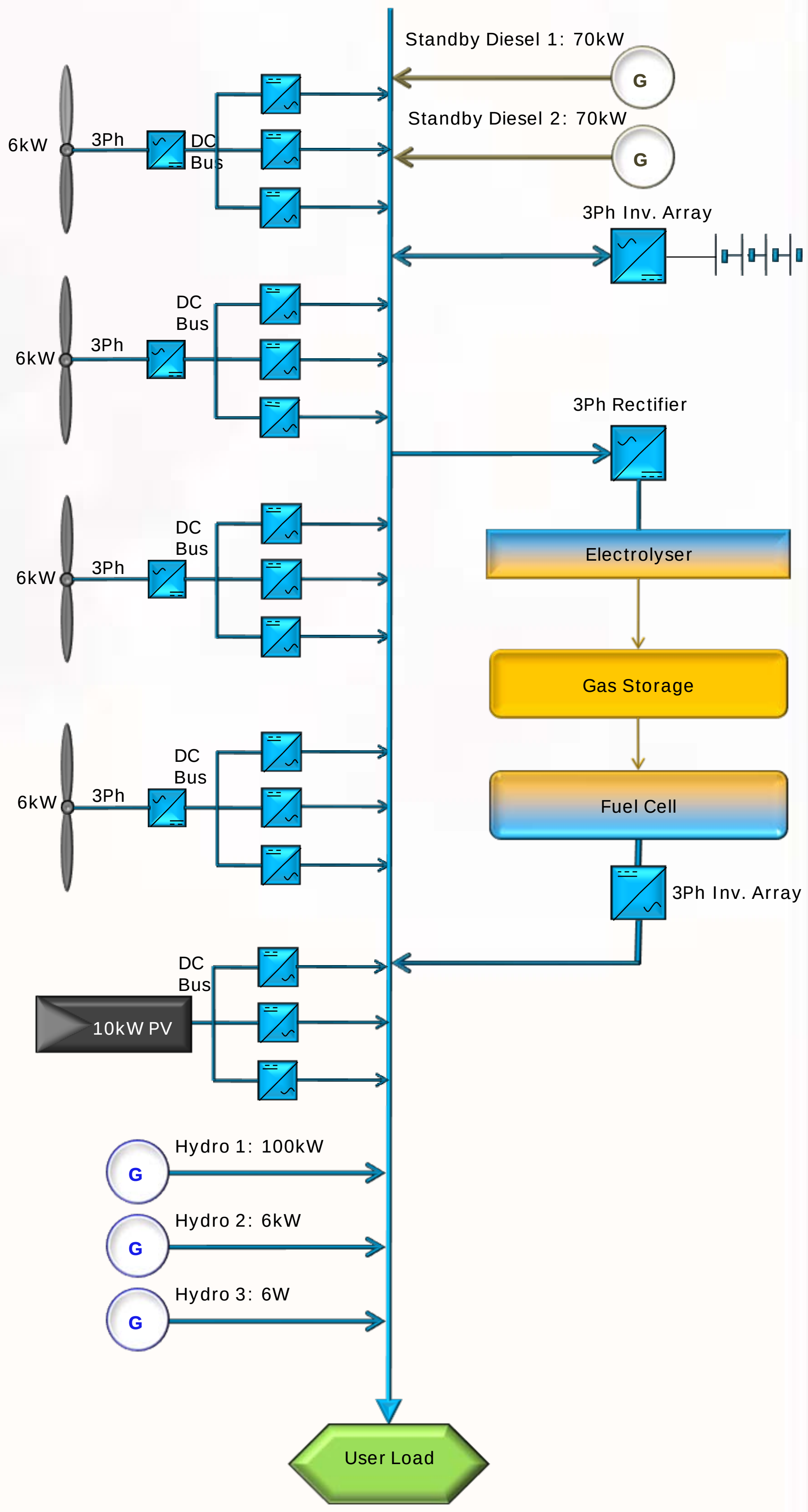


**Fig.3**: Simplified Schematic of hybrid energy system used for modelling impact of hydrogen energy storage.