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DEPLOYMENT OF HYDROGEN TECHNOLOGIES IN NEW ZEALAND

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ABSTRACT

In 2013 the implementation in New Zealand of hydrogen technology took a significant step forward when the private sector company H2NZ facilitated the establishment of a nationally focused Hydrogen Technology Development Committee (HTDC) based at Unitec (NZ) to provide commercially viable renewable hydrogen based energy solutions. The scope for deployment of hydrogen technologies initially encompasses transport, stationary equipment and heating. A New Zealand Branch of the International Hydrogen Energy Association will be established as a promotion and information dissemination entity. Concomitantly commercial activities are being managed by H2NZ; education and research by Unitec; and expert advice and facilitation of commercialisation by Callaghan Innovation, a government agency. Industry partners are engaged at all levels to maximise potential for commercialisation. In December 2013 H2NZ through the HTDC launched the development of two projects. These are a hydrogen powered quad bike and a zero grid energy residential house incorporating on-site hydrogen storage. Both are planned to be built by the end of 2014. In addition H2NZ is facilitating the commercialisation of UniSyD techno-economic system dynamics modeling software through collaboration between the joint intellectual property owners Unitec and the University of Iceland (UI), and the New Zealand National Energy Research Institute.

Keywords: Hydrogen, Renewables, Deployment, Quad bike, UniSyD

1. Introduction

New Zealand is located in the South Pacific (Fig. 1). It has an estimated population in 2013 of 4.4 million (Statistics New Zealand, 2013) and a land area of about 268,680 sq. km encompassed in two main islands. A community based hydrogen energy system was first demonstrated in New Zealand in 2007. After a two year period of evaluating materials and technologies, the “HyLink” renewable hydrogen project was commissioned at Totara Valley near Palmerston North. This utilised a 2.2kW wind turbine generator, a 400 W PEM electrolyser and a 1 kW PEM fuel cell (Fig. 2).

An unusual feature of this demonstration is that the wind generator and electrolyser were isolated from the community with a 2 km hydrogen pipeline being the only energy carrier connection. The hydrogen system was part of a range of distributed energy technologies installed to demonstrate the provision of heat and electricity for the

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local rural community consisting of three farmhouses and a collection of farm buildings.

The community was grid connected throughout the project but had a strong desire to use as much local renewable energy as possible. This "engineering proof-of-concept" HyLink system consisted of about 2 km of 18 mm diameter medium density polyethylene (MDPE) pipeline for hydrogen transmission and storage, connected at the supply end to the 4 bar pressure PEM electrolyser, and at the demand end to the 1 kW PEM fuel cell, which was connected to the distribution network. Heating by hydrogen combustion was not deployed since the pipeline terminated at a woolshed.

The hydrogen produced via electrolysis at the wind generator site directly pressurized the pipeline, in which the hydrogen was conveyed over the 2 km length. The pipeline provided a storage volume of 400 litres, equivalent to about 5 kWh at 4 bar gauge pressure, with virtually no energy loss (Fig. 3).

The project successfully demonstrated the feasibility of producing hydrogen from wind at a very remote location, piping it to a community site where it was converted to electricity in a fuel cell and exported to the distribution network, using existing technologies. This was the first such demonstration in New Zealand, and most likely anywhere in the world.
In 2011 a new pilot project utilising hydrogen was established on Matiu/Somes Island in the Wellington Harbour. A public assess monitor website shows the current production rate of hydrogen and the amount of renewable energy used to produce hydrogen in the last clock-hour (New Zealand Department of Conservation, 2013). Due to cultural factors and consenting requirements this hydrogen energy system is located at a single site as illustrated in Fig. 4. The island electricity system is independent of the mainland and consists of a small three phase distribution network supplied from a hybrid renewable energy system consisting of a 6 kW wind turbine, 3.8 kW of solar panels and a diesel generator. The combination of wind turbine and PV works very well at this site and has exceeded expectations by providing nearly all of the island’s present electricity needs (Fig. 4).
Surplus electricity from the renewable energy system is used in the 1.2 kW alkaline electrolyser to produce hydrogen gas. This is stored in the two 330 mm diameter underground pipes. Approximately 10kWh HHV of energy storage is available. To achieve best energy efficiency and further reduce fossil fuel imports to the island, the hydrogen will be used as a thermal fuel to replace LPG for water heating and cooking. Currently, a hydrogen barbeque has been provided and water is heated at the workshop for washing and general use. Following 15 months of successful operation, in which over 2 MWh of hydrogen fuel has been produced, a phase 2 project is being developed. This will involve underground distribution of the hydrogen to a further public BBQ and to hydrogen fueled domestic water heaters located at two permanently occupied houses. The overall aim is to eventually achieve close to 100% renewable energy use on the island.

2. Recent developments

In 2013 a private sector company that is focused on commercialising hydrogen technologies, H2NZ, facilitated the establishment of a nationally focused Hydrogen Technology Development Committee (HTDC) based at Unitec. The primary purpose of the HTDC is to source, develop and assemble hydrogen technologies into commercially viable systems and mechanisms that will minimise the environmental footprint. A flow chart outlining organizational links of the HTDC for the deployment of hydrogen technology is outlined in Fig.5. The HTDC is composed of the principal industry partner H2NZ, representatives of tertiary institutes including Unitec, commercialization advisers and technology specialists from Callaghan Innovation, and other industry partners willing to contribute in kind in the expectation of a commercial return in the future. Within two months of first meeting, the HTDC obtained permission from the International Association for Hydrogen Energy (IAHE) to establish the New Zealand Association for Hydrogen Energy (NZAHE). While the NZAHE has not yet been constituted it will liaise closely with other renewable energy focused associations in New Zealand. These include the Sustainable Electricity Association New Zealand, New Zealand Wind Energy Association, New Zealand Geothermal Association, Solar Association of New Zealand, Bioenergy Association of New Zealand and the Association for the Promotion of Electric Vehicles. The NZAHE will also seek to raise awareness within New Zealand government agencies of potential applications of hydrogen in the economy and also provide a vehicle for dialogue, information dissemination and education.

Fig.5. National organizational structure for supporting the deployment of hydrogen technology.
3. Hydrogen energy in New Zealand

The deployment of hydrogen technologies in New Zealand is constrained by the absence of hydrogen infrastructure for delivery and refueling, in addition to the absence of regulations to ensure the safe utilization of hydrogen fuel. New Zealand is a sparsely populated mountainous country with ample renewable energy resources, particularly hydro, wind, solar, biomass and wave. Connell Wagner (2008) showed that the wind energy resource at a generation of cost less than 10 US¢/kWh is three times larger than the electric energy generated in New Zealand in 2008. This equates to wind energy potential in 2013 of about 0.23 kWe/capita or 3.71 kWe/km². New Zealand is isolated from other countries so cannot share electricity supply to balance demand. Depending on fluctuation in annual precipitation, the current electricity generation mix is approximately 65% to 70% renewable (mainly hydroelectric). There is a national aspiration to achieve 90% renewable generation by 2025. The climate is temperate with modest seasonal average extremes in temperature. With a predicted increase in intermittent renewable generation, ability to address the inevitable mismatch between supply and demand new storage technologies will be required to reach the target 90% mix. Hydrogen used as a renewable energy vector can contribute at all scales. New Zealand is an ideal environment in which to develop and test these novel energy systems at the smaller distributed scale, particularly in the efficient and globally competitive export oriented farming industry.

4. Projects

The first concept adopted by the HTDC for the distributed deployment of hydrogen energy technology utilises the HyLink system as outlined in Fig. 3. This initiative leads directly into the development of infrastructure for hydrogen based external-energy independent farming systems. We define an energy independent farming system as one in which energy resources within the farm boundaries are utilised for productive farming operations. A hydrogen based energy independent farm is one in which hydrogen fuel is generated on the farm, e.g. by electrolysis using renewable electricity generated on-site with some or all of micro-wind, micro-hydro and photovoltaic technologies. The local energy systems can in principle provide for all energy needs including hydrogen for use as fuel for prime movers such as vehicles and farm machinery. Important reasons for building this concept around a hydrogen infrastructure is the need to achieve cost-effective energy storage (both stationary and transportable), and the ability of chemical fuels such as hydrogen to deliver high power (i.e. do work) at relatively modest conversion technology cost. These characteristics are not currently available from electricity alone. The longer term objective is to develop, test and deploy customised renewable energy based technology packages that will allow farmers to be independent of the electricity grid and delivered fossil transported fuels.

To demonstrate the strategic role that hydrogen could play in energy independent farming, in late 2013 two sub-projects were initiated by H2NZ and the HTDC. The first sub-project is the development of an advanced technology electric farm bike (UniQuad).

5. Hydrogen Technology Development Partnership (HTDP)

UniQuad will be the first hydrogen powered electric quad in New Zealand. The UniQuad will demonstrate the feasibility of developing and operating a bike that will be both safer than conventional quad bikes but will also be hydrogen powered and therefore zero emission. UniQuad will significantly reduce accidents due to overturning and will be able to be marketed with a variety of drive options. These include internal combustion engine, Li-ion battery, PEM fuel cell and combinations of these. The suspension system under development will also be able to be retrofitted to some existing bikes. The project has two foci, each with substantial benefits.

The first focus aims to enhance national capability in the development of renewable energy technologies. The bike will:

- Have a much longer range before requiring refuelling than a battery powered electric quad.
- Provide the staff of New Zealand educational institutes the opportunity to both up-skill in electric based technologies and contribute to the development of the first hydrogen powered fuel cell vehicle assembled in New Zealand.
• Raise awareness of the potential for zero emission energy independent farming.
• Engage industry with a range of equipment suppliers who are participating in hydrogen based technology developments overseas.
• Raise awareness of the need for government policy to include a hydrogen focused future as an optional energy pathway.
• Improve farming practice by reducing farm quad bike fatalities and injuries and the associated costs to the government.
• Have the potential to reduce both greenhouse gas emissions and engine noise levels due to the use of renewable hydrogen fuel.
• Provide an option for improved security of operation in the farming sector with a quad that can be fuelled on the farm without being dependent on imported fossil fuels.

The second focus aims to improve safety of quad bikes for farm use. The UniQuad will be designed to contribute to a significant reduction in quad bike injuries and fatalities that constitute 28% of all work-related farm deaths in New Zealand (Ministry of Business Innovation and Employment, 2012).

To achieve this UniQuad will incorporate a self-levelling suspension designed to substantially reduce the accident rate by keeping the lateral centre of gravity over the centre of the axle even while sideling along slopes at angles of up to 45 degrees. The self-levelling suspension will be designed both as a retrofit kit to existing bikes and also as an advanced technology element of the hydrogen electric Quad. Following assembly in 2014, the performance of the bike will be assessed in 2015 using dynamometer measurements of torque, hydrogen fuel consumption, and fuel cell performance. The stability and traction capabilities of the bike will also be investigated and the electronic control systems optimised.

Hydrogen technology for the UniQuad will be selected based on a global search via the web, industry referrals and recommendations from both staff and industry. Substantial work has already been undertaken to identify possible suppliers. Equipment to be sourced includes electric hub motors (~4x5kW), fuel cell (~25 kW), Li-ion battery (~1 kWh), and hydrogen fuel tank (~ 1kg at 350 bar).

The second sub-project is the development of a grid-connected house incorporating hydrogen energy technology. The aptly named HydrogenHouse is 250 sq. m. with a heated pool. The house is located on the shores of Lake Taupo in the central North Island and will be completed in late 2014. The HydrogenHouse incorporates passive solar design including high specific thermal mass materials such as concrete along with tinted argon filled double glazing and solar thermal hot water heating. The roof will be clad in high efficiency photovoltaic arrays. Hydrogen gas will be generated and stored on site for provision of thermal services including high rate swimming pool heating. External delivery of renewable hydrogen fuel may be used when required to make up seasonal shortfalls. An advanced energy management system will determine how to best utilise the available on-site energy resources (solar PV, stored hydrogen energy and back up LPG) in relation to imported electricity costs.

Planning for the development of energy resources on the farm pilot site has commenced. Potential wind, hydro and PV resources have been identified and it is planned to integrate production from most energy rich site with a low pressure hydrogen storage facility via an on-farm medium pressure hydrogen pipeline network. Design of this infrastructure is proceeding.

In addition to these initiatives, H2NZ in cooperation with the New Zealand National Energy Research Institute are supporting the development and commercialisation of UniSyD techno-economic system dynamics software developed at Unitec. UniSyD models the interactions between entities in an energy system including electricity and hydrogen generators, and vehicle fleets using their detailed performance specifications (Leaver et al., 2009). UniSyD has a high level of technological specificity and uses a transparent mode of programming that makes the software easily transportable between programmers. The software is useful in the deployment of hydrogen technologies as it is capable of modelling the impact of hydrogen energy on the energy economy both at a micro and macro level. UniSyD has been adopted as the platform of choice by the University of Iceland for modelling the Icelandic energy economy and the model is expected to be shortly extended to encompass other Scandinavian countries.
6. Discussion

The potential for short term commercial return has enabled the projects to already attract other industry partners. The profile of the hydrogen technology in UniQuad will be raised by exhibiting it at the World Hydrogen Technologies Convention 2015 in Sydney, Australia.

Other projects are planned to reinforce the viability of fueling energy independent farming equipment. These include tractors, forklifts, other farm machinery and water craft. It is planned to go beyond the concept of energy independence and investigate the export of hydrogen energy intensive products including ammonia for fertilizers. Due to the limited availability of research funding associated with and the low population in New Zealand, international involvement in these energy independent farming systems and associated projects will be strongly encouraged.

7. Conclusion

New Zealand is ideally positioned to take advantage of the unique features of hydrogen as a renewable energy carrier. It has an abundant resource of viable wind energy sites many of which are located in rural environments. There are substantial needs and opportunities within the farming industry to utilise on-farm energy resources. Hydrogen is an attractive energy carrier for this purpose.

A new entity the Hydrogen Technology Development Partnership has been formed to commercialise technologies and systems associated with this advantage. The Partnership aims provide commercially viable renewable hydrogen based energy solutions in the deployment of hydrogen technologies initially encompassing a focus around farming with applications in transport, stationary equipment and heating. In December 2013 the HTDC launched the development of a hydrogen powered quad bike and a zero grid energy residential HydrogenHouse. Both are planned to be built by the end of 2014. In addition the commercialisation of UniSyD techno-economic system dynamics software is underway to support national energy systems planning. The Partnership is seeking further international engagement and collaboration to enhance the global deployment of hydrogen technologies.

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REFERENCES


