Clean Energy Innovation Hub

ATCO H2 MICROGRID: 2018/ARP008

Project results and lessons learnt

Lead organisation:	ATCO		
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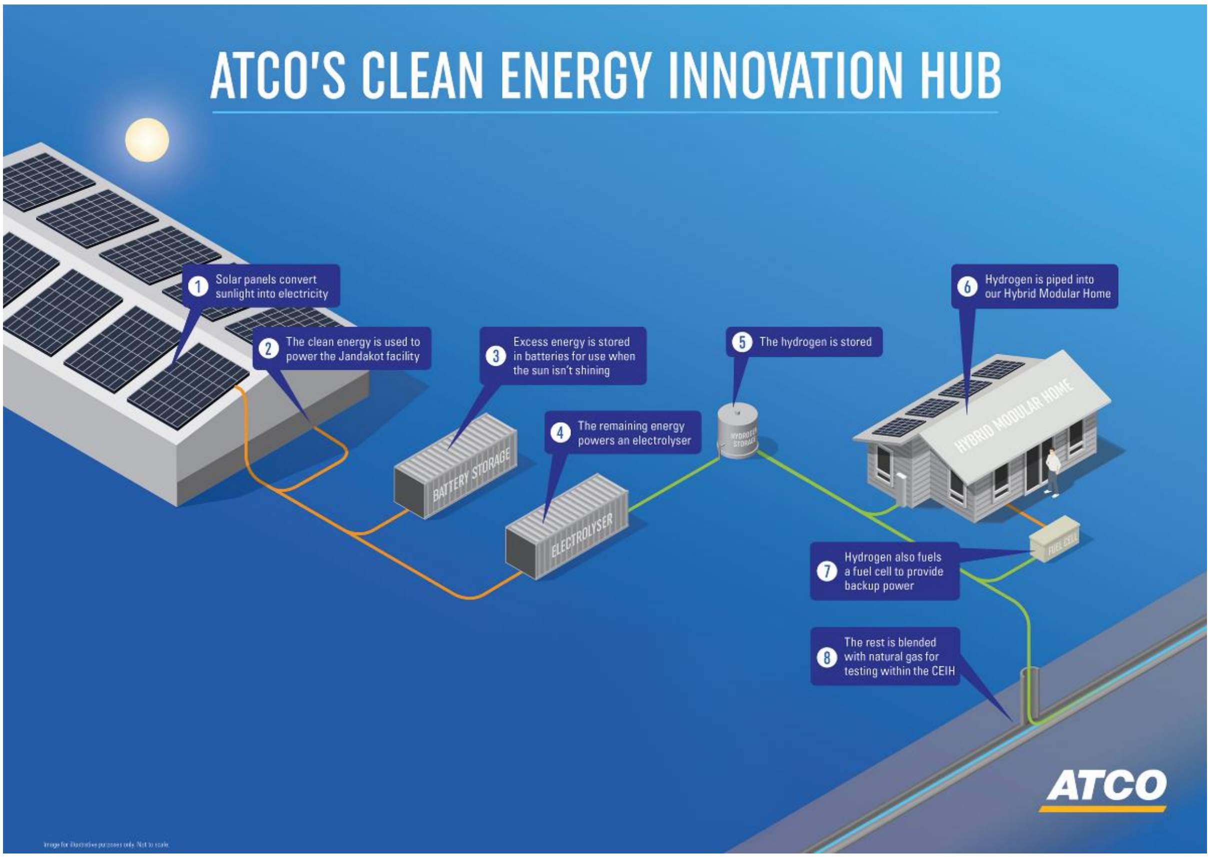
Executive Summary

ATCO's Clean Energy Innovation Hub (CEIH) aims to investigate the potential role of hydrogen in the future energy mix by developing and utilising an industry-leading research facility. Testing will be conducted on a microgrid set-up enabled by renewable gas technology (including hydrogen) and on the integration of renewable gas with solar and batteries.

ATCO's CEIH is an Australian-first, which integrates renewable hydrogen production and fuel cell technology with a renewable energy stand-alone-power-system in a *"living lab"* microgrid setup. At the CEIH, 1003 solar panels will produce renewable energy to supply ATCO's Jandakot Operations Centre. Excess renewable energy generated from the 300 kW of rooftop solar photovoltaics is used to produce renewable hydrogen from a 260 kW electrolyser. Excess renewable energy is also stored for non-sunshine hours-usage in 500 kWh (478 kWh useable) of onsite battery energy storage. Pure green hydrogen is stored in a 30-bar high-pressure storage vessel and is thereafter, either distributed within the microgrid as a blended fuel for normal consumption or used as a direct fuel for appliance testing as well as for back-up power to a residential display home.

The project has produced seamless integration of hydrogen production and renewable electricity generation.



Project Overview

Project summary

The purpose of this project is to demonstrate the seamless integration of renewable energy assets and hydrogen can be safely and efficiently introduced into the natural gas distribution system that will contain hydrogen levels beyond those in the current gas specification.

Australia is committed to reduce emissions to 26-28 per cent on 2005 levels by 2030. The majority of emissions in Australia arise from the combustion of fossil fuels and consequently electricity generation is the largest single contributor to CO2 emissions, at 37.2 per cent of inventory emissions. One major challenge and significant obstacle to meeting its commitments is reducing the carbon intensity of heat as highlighted by the Parliament of Australia in its 'How much Australia emits' report.

ATCO maintains a safe and reliable network delivering approximately 25,500 terajoules (TJ) per year of natural gas over its coastal gas distribution network. Whilst heat demand is highly seasonal, gas in Western Australia is readily available and capable of meeting peak heat requirements. Low carbon heat via ATCO's gas distribution network aims to address three key issues for Australian energy consumers:

1. Reductions in their emissions profile;
2. Maintaining an affordable energy service; and
3. Ensuring their service is reliable into the future.

Like natural gas, hydrogen can be used to provide essential heat, however unlike natural gas, when hydrogen is burned there are no carbon emissions with only heat and water vapour as its products. Within the context of ATCO's business, emissions could be reduced by lowering the carbon content of gas through blending with hydrogen and subsequently improving the network's current Unaccounted for Gas (UAFG) contribution to greenhouse gas emissions.

Natural gas is seen by many as a transition fuel with attention placed on large scale electricity generation through gas turbines, which can provide important balancing and quick start peak and frequency control. However, gas is reticulated right to the door of millions of Australians, covering residential, commercial and industrial sectors, and ATCO have been considering whether that resource could be utilised to assist higher renewable penetration at the domestic and commercial scales. Smaller optimised and strategically placed gas generators, including Combined Heat and Power applications (cHP), working with Photovoltaic (PV) and batteries in a micro-grid setting can offer higher reliability, more secure and more commercially attractive energy options for many customers than purely grid supply or, in many cases, diesel backup systems. Ultimately, natural gas can be augmented with lower carbon options, such as hydrogen, driving towards an effective combination of low emissions options.

Since June 2016, ATCO has been successfully operating a demonstration-scale residential Hybrid Energy System (HES) in Vasse, Western Australia. The HES integrates 3 and 5 kW rooftop solar systems and 9.6 kWh battery storage with 8 kVA natural gas fired back-up power generation – a first of its kind in Australia. Our successful residential HES trial project delivered insights into the role of natural gas as a reliable back-up power source in a residential hybrid energy mix, and addressed power intermittency issues. This project provided a solid foundation to build-on for ATCO's Clean Energy Innovation Hub.

ATCO's CEIH project focusses on testing our proposition by building a green hydrogen micro-grid at commercial scale located on our main operations centre, in Jandakot, Perth. The project allows ATCO to trial, at commercial scale, the seamless integration and control of gas generation and renewable energy technologies in a setting that allows maximum testing flexibility without risk of impacting end-users. Further, ATCO sort to introduce into the 'sustainable energy eco-system', on-site hydrogen production from excess solar power generation, and begin testing and trialling of various technologies, regulatory barriers, standards and practical capabilities required to transition such systems towards cleaner energy future including hydrogen.

Project scope

ATCO sort to design and construct a commercial scale Hybrid Energy System (HES) micro-grid as part of a demonstration project at its Jandakot operational centre. The commercial hybrid energy system includes: solar Photovoltaic (PV) array, commercial scale batteries and an existing natural gas fired generator to meet its own energy needs and be scalable to enable performance and integration testing of other makes and models of solar PV panels, batteries and gas fired generators.

The HES green hydrogen Microgrid not only demonstrates technology integration and control, but also evaluate the commercial viability of Microgrids with and without green hydrogen. The demonstration project will identify if the reticulated natural gas network can act as a peaking back-up system to a commercial scale Microgrid, self-consumption electrical solution or provide peaking generation/ancillary services to the electrical grid via the individual 'zoned' sites within AGA's Jandakot precinct.

The project demonstrates how a commercial-scale Microgrid integrating solar, battery and gas generation can address availability and variability issues inherent in intermittent renewable energy technologies by working synergistically with other components within the Microgrid. The project deploys solar PV and Battery Energy Storage System (BESS) integrated with the site's existing 200kVA natural gas fired engine. The system balancing is controlled by a 'cluster controller' and is synchronised with the Western Power distribution network. The system is designed to disconnect from the central distribution network thus 'slanding' the microgrid.

The project also introduces on-site production of hydrogen from excess solar energy, and begins the exploration of technology, regulatory requirements, standards and capabilities required to transition such systems towards a higher hydrogen contribution and integration. The latter incorporating use of the existing gas distribution network, existing power network grid support and direct use applications.

This demonstration project has three main overall objectives.

Firstly;

- *To identify how disruptive technologies, customer desire for control, and their growing acknowledgement of climate change would potentially drive C&I energy connections away from gas and towards self-generation and consumption of electricity;*

Secondly;

- *To develop a Microgrid business model that uses natural gas as a key enabler as mitigation and drive energy consumption towards natural gas; and*

Thirdly;

- *To investigate the feasibility and role of hydrogen production, distribution and use in a Microgrid set-up.*

The scope included the following:

1. **Learn and understand the changes in the energy industry and R&D latest technology**
   a. Install 3 x 100kW plug-and-play different PV supplier systems to be able to analyse performance differences and determine strategic partnerships.
   b. A 500 kWh battery energy storage system.
   c. An electrolyser to produce hydrogen for blending with natural gas and use as energy storage.
   d. A commercial scale gas engine with the ability to accept blends of natural gas and hydrogen.
   e. A small fuel cell to demonstrate the potential for power to gas to power for residential customers.
   f. Allow for future hydrogen fuelling station.
   g. A gas engine/turbine/fuel cell testing facility for 5kW to 1000kW equipment to be trialled; and

2. **Build, grow and nurture trusting supplier relationships**
   a. A supplier outreach program to source diverse equipment to test and inform a future microgrid supply chain.
   b. Key relationships to be built with:
      - Gas engine/turbine suppliers
      - Inverter/controller technologies
      - PV Suppliers
      - Battery suppliers; and
      - Hydrogen electrolyser suppliers.

3. **A technology showcase for promoting ATCO**
   a. An architecturally inspired rooftop PV installation (3 x 100kW)
   b. Engine testing facility that allows for mobile cranes to install and remove generators
   c. A modular inverter & control system; and

d. Data visualisation and energy optimisation system.

4. **ATCO staff engagement and energy value understanding**
   a. Produce a live virtual bill that details AGA's energy unbundled contract and drivers:
      - Outline the real time impact on energy value streams, network value, capacity markets and environmental emissions; and
      - Provide real-time monitoring on key thresholds for network and capacity value.
   b. Live data stream in centre/foyer/lunchrooms:
      - Outline key energy flows from grid, PV, gas powered air conditioning, battery fill, and gas generator; and
      - Provide real-time remote controls to form part of staff/training experience.
   c. Display site load profile and the energy market trading profiles to:
      - Encourage informed behaviours to turn off loads or turn on the generators; and
      - Interface with links from AEMO on total grid output.

The key components of the microgrid aspect of the system are:

- 370 kW (300 kW useable) solar PV array including inverters
- 500 kWh (400 kWh usable) battery storage system
- Existing 200 kW gas generator for running on blends of natural gas and hydrogen
- Allowance for future hydrogen vehicle fuelling station
- 3 connection points for testing, sizing and future "firm capacity" generator connections

The key components of the hydrogen R&D aspect of the project include:

- 150 kW hydrogen electrolyser system and storage
- 1.1 kW residential scale hydrogen fuel cell
- Natural gas/hydrogen blending and testing equipment

Outcomes

Site operation

On 18 July 2019, ATCO officially opened its Jandakot site (CEIH) for operation. ATCO successfully completed integration, testing and commissioning of 300 kW of solar photovoltaics, 500 kWh of lithium Ion batteries storage, and an existing 200 kVA natural gas-fired generator with a 23 tonne

per annum state-of-art hydrogen production plant. The fully integrated hydrogen production plant includes a Proton Exchange Membrane (PEM) electrolyser, high pressure hydrogen storage vessel, custom-built Pressure Reduction Station and hydrogen/natural gas blending station, and a suite of downstream consumers. The downstream consumers include a 1.2 kW hydrogen fuel cell and existing natural gas appliances: Gas Powered Air Conditioning (GPAC), hot water boilers, gas barbeques, heaters and cooktops.

Capacity and use of electrolyser

The Electrolyser model selected is a Proton C30, and has capacity to generate up to 65 kg/day (2.71 kg/h), consuming 64.5 kWh/kg electrical power (175 kW at 2.71 kg/h). Hydrogen is generated at 58°C and 30 barg by electrolysis of de-ionised water, producing low pressure oxygen as a by-product, which is vented to atmosphere. Utility water is delivered to the Electrolyser as feedstock, from our site's mains water system, for de-ionisation prior to electrolysis. The maximum required water supply rate is 26.9 litres/h at 1– 4.1 barg and 5 – 40°C. The de-ionisation process produces a wastewater stream which is continuously drained during Electrolyser operation and captured for wastewater use on our site.

The Electrolyser will only operate to produce hydrogen when there is sufficient electrical power available from the Solar System after the battery storage has filled. As such, Electrolyser power availability is determined by a limited solar window, and it is designed to operate once daily for two to four hours. Therefore, in order to provide hydrogen to the consumers outside the solar window, it was necessary to install a Hydrogen Storage Vessel. When the Electrolyser operates, it will pressurise the vessel to a maximum pressure of 30 barg. Hydrogen is provided to the following consumers from the storage vessel, when there is sufficient inventory:

- Natural gas blending (via a proportioning valve set) to gas consumers
- Fuel Cell

Capacity and use of hydrogen fuel cell

The Fuel Cell model selected, PEM FCM-801, has a rated net power of 1.2kW @ 48V or 0.96kW @ 24V consuming 60 grams hydrogen gas as fuel at pressure between 500mbarg and 800mbarg per kWh. ATCO's Jandakot site microgrid includes a residential display hybrid home. The fuel cell has been integrated with the power system of the hybrid home to provide back-up power. The fuel cell is designed to operate during periods where the hybrid homes' primary sources of power (solar and batteries) are depleted.

Use of gas appliances

ATCO's Jandakot site consists of 6 x 85 kW, 1 x 35 kW and 2 x 18 kW GPAC units, 3 x domestic gas ovens and cooktops, 8 x instantaneous hot water heaters, 6 x gas barbeques, 2 x open fire gas heaters and 1 x open fire pit.

Introducing blended hydrogen and natural to downstream consumers is complex and requires a coordinated approach. ATCO will introducing hydrogen into natural gas at 0.5 per cent increments up to a maximum 10 per cent, over an extended period of time. ATCO foresees gas appliance usage occurring over an 18 to 24 month period post go-live of the microgrid facility.

System performance data including solar, gas and hydrogen integration and use.

Due to significant technological advances in recent years, harnessing the value of real-time and historical data from ATCO's hydrogen microgrid, existing power generation assets and operations, and then combining with data from ATCO's enterprise systems (and valuable data from a multitude of other data sources), presented as a practical, realistic and cost effective opportunity. By provision of easy, secure, self-serve access to operational data and advanced data analytics tools, improvements in productivity, efficiency, asset management and business planning decision making can be achieved by contributors at all levels across the business.

Therefore, ATCO designed and installed Operational Intelligence Data (OID) Infrastructure to function as a Data Abstraction Layer, which securely provides the system's operational and performance data to ATCO's existing business systems and users to interact, analyse and contextualise the performance and operations of the system. Performance data can be sourced at up to one minute intervals from ATCO's Operational Intelligence platform. Performance at the time of commissioning is as follows:

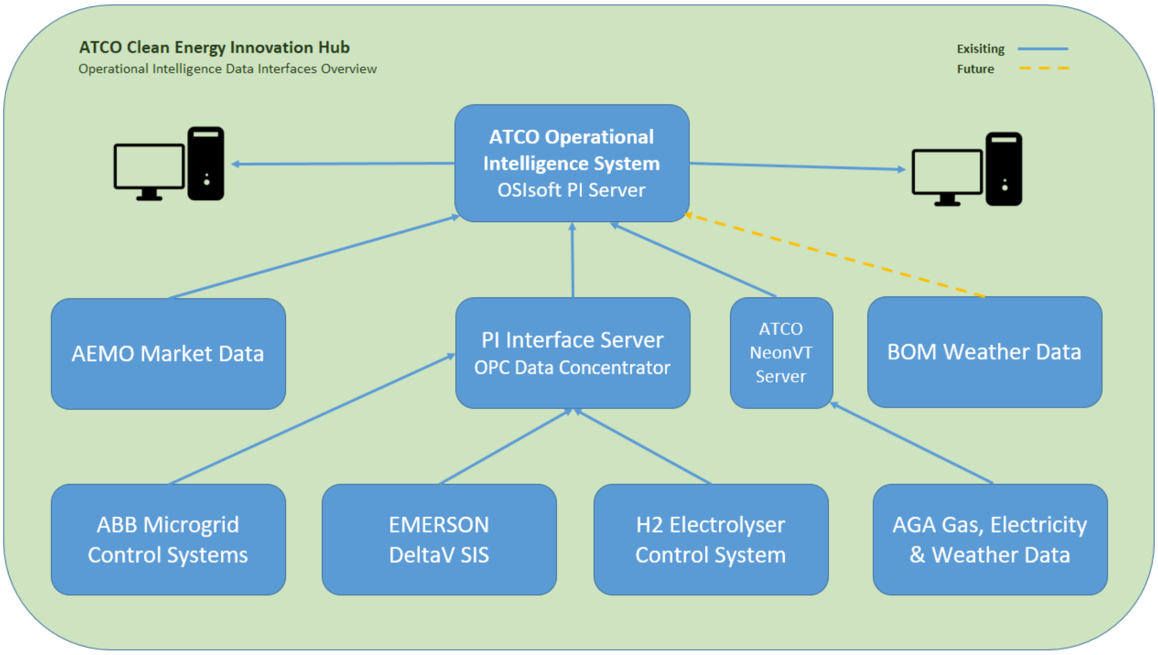
- Solar PV: maximum production up to 300 kW
- Battery Storage: Maximum useable capacity 474 kWh

- Hydrogen production: Daily maximum up to 65 kg or 30Nm³/h
- Natural Gas/Hydrogen blend: 38 m³/hr with maximum hydrogen blend of 3.8 m³/hr

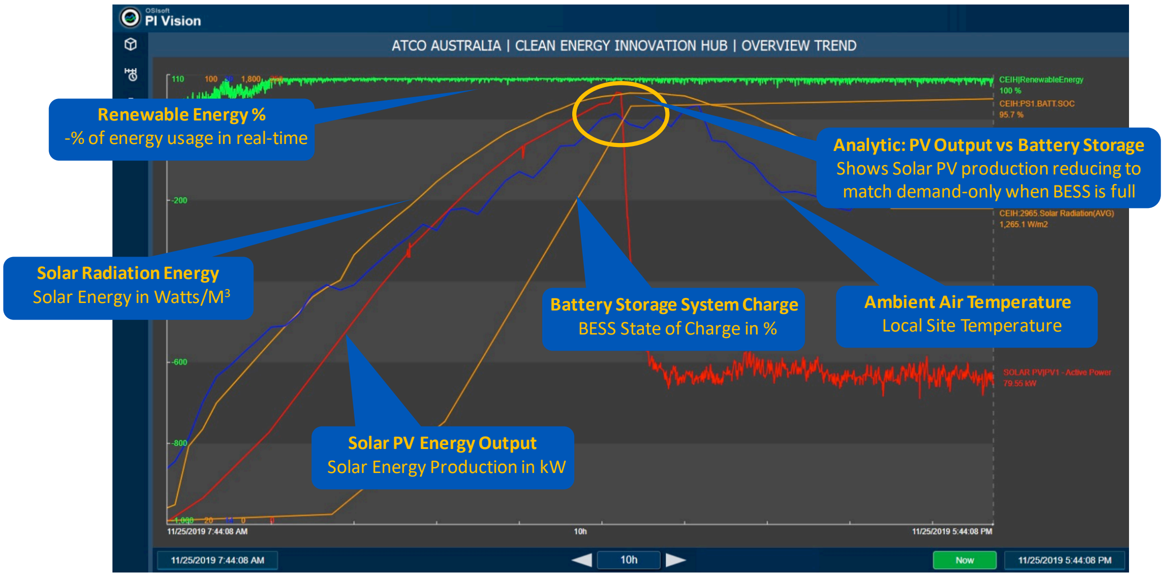
In managing the complexity of the hydrogen integrated microgrid, ATCO identified the requirements for the enterprise Operational Intelligence (OI) Data Infrastructure and Advanced Analytics & Reporting system and implemented it in order to improve the operational and enterprise data accessibility, contextualisation, visualisation and analytics; in order to ensure increased productivity and efficiency, improved asset management and operational planning, and enhanced business decision making.

The OI Data Infrastructure functions as a Data Abstraction Layer, securely providing the hydrogen-microgrid's operational data to other business and enterprise applications, enabling both business systems and users to interact, analyse and contextualise operational data, subsequently transforming raw data into valuable information to further augment operational and business decision making and strategy formation processes.

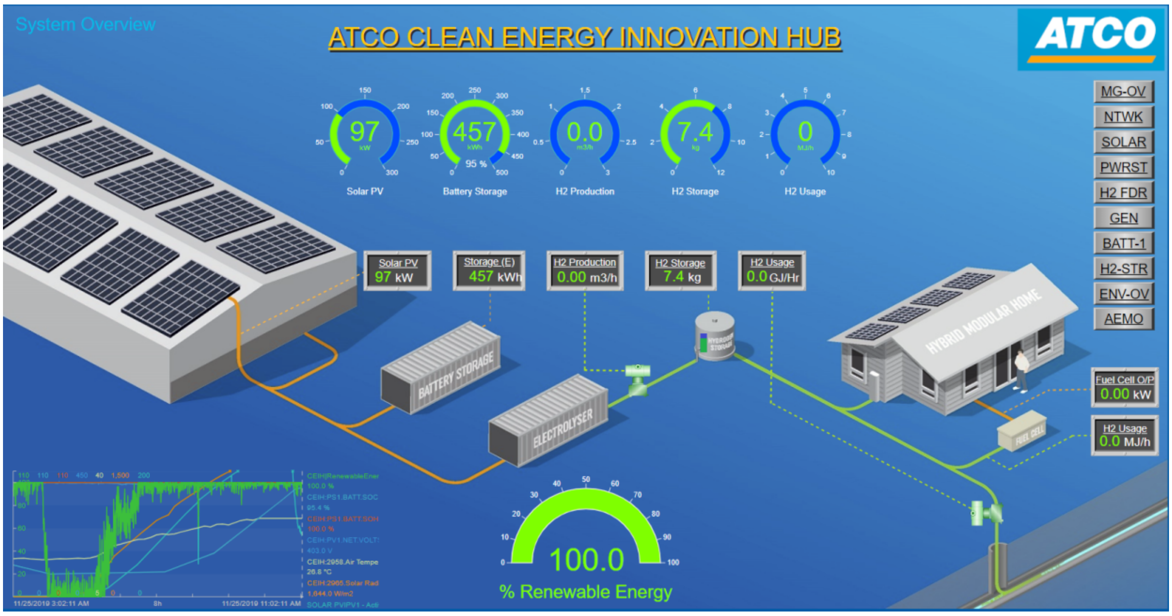
The system architecture is designed with the capability to scale to encompass other data sources, users and systems or any assets or operations that ATCO Australia acquires, builds owns and/or operates in the future. The figure shows the basic data integration overview.



Data from three external control systems i.e. Microgrid, Safety and Electrolyser is sourced via Programmable Logic Controller (PLC), Human-Machine Interface (HMI) and Supervisory Control and Data Acquisition (SCADA) systems. Data from ATCO installed and controlled Electricity, Gas and Weather Station meters is sourced via an Internet of Things interface and finally, third party data sources are extracted via the internet from sources such as AEMO for energy market data, BOM for weather data. The data is analysed and displayed on Data Analytics Clients. The graph below is a typical example of analysis of the various data sources.



The illustration below show a typical real-time Data Analytics Client display of the site's energy balance.



Provision of commissioning plan certified by a qualified party.

During the construction phase, ATCO produced an overall commissioning plan to provide direction for the commissioning tasks during construction. The plan focused on providing support for the specifications and provided forms for the application of the commissioning process. The commissioning plan with produced and endorsed by third party, subject matter experts, Advisian.

ATCO's H2Micro system is an integration of existing, commercially available technology. Therefore, manufacturer approved commissioning plans for individual components was used throughout the commissioning process.

Blending performance trials

In November 2019, the CEIH pressure reduction station (PRS) completed its first active test blending of 5-25 vol% hydrogen into natural gas on the site. Flow trials involved venting blended gas through non-interconnected pipework purge poles, rather than consuming in gas appliances. The purpose was to test system functionality, control, and safety systems and calibrate H2 %vol blending ratios compared to %open settings on the flow control system.

Measuring % hydrogen

The specially configured % hydrogen measuring gas chromatograph (**GC**) was commissioned by third party equipment manufacturing technicians with ATCO onsite operations and maintenance training being completed. For safe control reasons, the GC is configured to close all hydrogen valves and stop gas blending if vol% H2 level reaches 20%; while natural gas would continue to feed connected gas appliances with no interruption to routine operation.

Controlling % hydrogen input

The GC provides a constant feedback loop into the Proportional Integral Derivative (PID) controller to operate the blending system hydrogen flow rate input. System calibration was completed allowing excellent control of the hydrogen blend ratio during steady state flow conditions with accuracy ± 0.1%.

System "stress" testing of gross non-typical changes to the flow rate from 30m3/h down 5m3/h (83% flow decrease), saw the steady state 5 ± 0.1% H2 gas blend temporarily increase to 18% H2 for a 2-minute GC cycle time period update, before decreasing back to the steady state target value within approximately 10 minutes.

The gas blending has several control options including gas meter pulse output proportional control. The ratio of high frequency gas meter pulses from the identical low pressure natural gas vs hydrogen meters are directly compared in the PID and they hydrogen flow rate control valve is instantaneously adjusted to match the natural gas pulse rate ratio. One technical issue found was a programming error that prevented the system from working as designed which is being addressed by the PID manufacturer. The table below shows the preliminary hydrogen blending test results.

Test period (minutes)	Start-NG (m3)	End-NG (m3)	Total-NG (m3)	Start-H2 (m3)	End-H2 (m3)	Total-H2 (m3)	Total volume (m3)	Total flowrate (m3/h)	%H2	Control Valve position (% open)	%H2 on GC
1	5.151	5.411	0.260	3.667	3.680	0.013	0.273	16.380	**4.8%**	**5.0%**	
3	5.411	6.198	0.787	3.698	3.759	0.061	0.848	16.960	**7.2%**	**10.0%**	
3	6.198	6.988	0.790	3.772	3.835	0.063	0.853	17.060	**7.4%**	**10.0%**	
3	6.988	7.751	0.763	3.844	3.949	0.105	0.868	17.360	**12.1%**	**15.0%**	
3	7.751	8.496	0.745	3.958	4.104	0.146	0.891	17.820	**16.4%**	**20.0%**	
3	8.496	9.213	0.717	4.112	4.303	0.191	0.908	18.160	**21.0%**	**25.0%**	
3	9.213	9.909	0.696	4.311	4.538	0.227	0.923	18.460	**24.6%**	**30.0%**	
3	9.909	10.738	0.829	4.546	4.584	0.038	0.867	17.340	**4.4%**	**6.0%**	
3	10.738	11.550	0.812	4.593	4.636	0.043	0.855	17.100	**5.0%**	**7.5%**	**6.1%**
10	11.550	16.283	4.733	4.640	4.807	0.167	4.900	29.400	**3.4%**	**7.5%**	**5.4%**

The CEIH hydrogen blending system GC H2 vol% control and operation commissioning was very successful and can be reliably operated at low H2 vol% blending rates not exceeding 5% during supervised control. Following successful updates to the gas meter proportional feedback control programming scheduled for January 2020, there will be full redundancy interaction within the control system permitting reliable fully automatic operation.

Gas appliance operation on 5% hydrogen

The ATCO site has a daily natural gas consumption flow rate which varies over any given 24 hour period between 3 to 36m3/h. Gas supply is connected to 35 active, 12 training only and 2 disconnected gas appliances equally 49 in total. All connected gas appliances have been confirmed as suitable for a minimum of 10% Hydrogen blend either directly by the manufacturer or via Future Fuels Cooperative Research Centre (**FFCRC**) Type-A gas appliance testing at the Australian Gas Association (**AGA**) Melbourne test facility.

In December 2019 ATCO will commence the supervised introduction of 3-5% hydrogen gas blend to its onsite natural gas appliances for ongoing testing and trialling purposes.

Conclusion and next steps

- The CEIH will investigate opportunities to support clean energy, including the future role of hydrogen in the energy mix and its potential application to the wider economy.
- The data will provide technical insights into how hydrogen can act as a future balancing fuel for use in the energy grid.
- The CIEH is being built in conjunction with the redevelopment of the Jandakot Operations Centre where a new purpose built training centre will be used to test the application of hydrogen as well as upskilling our employees to prepare for a future energy workforce.
- The project will further position ATCO as a progressive, solutions-focused company that is part of the clean energy future and builds on our strategic plans to diversify and grow the business.

ATCO is playing an active role towards building a clean energy future and sees potential for significant growth opportunities for the business in new infrastructure as well as optimising our existing infrastructure.