1st May 2023

Current University of Canterbury research into hydrogen and potential practical applications

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Pro-Vice-Chancellor Sustainability

UC
UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Significant Examples of our funded research

- Safe storage of hydrogen
- The potential role of ammonia (fertilisers)
- Modelling – how to replace NZ's energy needs
- Green H from woody biomass
- A new type of "water splitter"

Funding for our research

1. New Zealand-German Green Hydrogen Research Partnership, announced August 2022
    - Opportunities that the programme provide for New Zealand research teams include working with German partners with world-leading expertise in their field, and gaining access to leading-edge European research facilities and equipment (Dr Ayesha Verrall, 16/8/22)
2. MBIE in partnership with the German Ministry of Education and Research
3. MBIE Endeavour (50% share of $12m)

Safe storage of H - A Green Hydrogen Geostorage Battery in Taranaki?

- About 70% of NZ energy comes from non-renewable sources, e.g., thermal peaking, transportation, process
- NZ *could* need up to 600,000 tonnes of H_2 annually. Need storage for 10% of that.
- Potential uses: using natural gas to manufacture fertiliser causes significant GHG emissions but we would need

- 5m of these bottle

OR – can we use underground storage?

- 100 of these balloons

Professor Andy Nicol and Dr David Dempsey suggest storing hydrogen in its liquid form alone may not be sufficient for the massive amounts we'll need if we transition to a H-based energy economy, so their research focuses on storing it as a gas.

Why in Taranaki?

- Depleted/declining gas fields, porous rock available
- Can use the green H in the fertiliser manufacture
- Transmission (pipeline) network.
- Export infrastructure.
- Energy workforce in the region
- Plenty of renewable energy to produce green hydrogen

Green H for fertilisers - cont

Dr David Dempsey

- Ammonia, used to make fertiliser, accounts for 2% of global carbon emissions. Currently the production of ammonia creates CO_2 as a by-product when the hydrogen is “cracked off” the methane.
- Fertiliser is essential for us to feed 40 million people from our country of only 5 million. If we want to keep doing that we will need to keep making fertiliser, and so companies are looking to decarbonise that with green hydrogen.
- Fertiliser production takes place in the Taranaki region….. which also has underground H storage potential….

Other Modelling

Dr Rebecca Peer and Dr Haas (Civil Engineering)

- developing an integrated energy system model to calculate pathways for sustainable transport, heating and electricity, aiming to measure and evaluate the future role of green hydrogen in New Zealand as the use of fossil fuels is phased out.

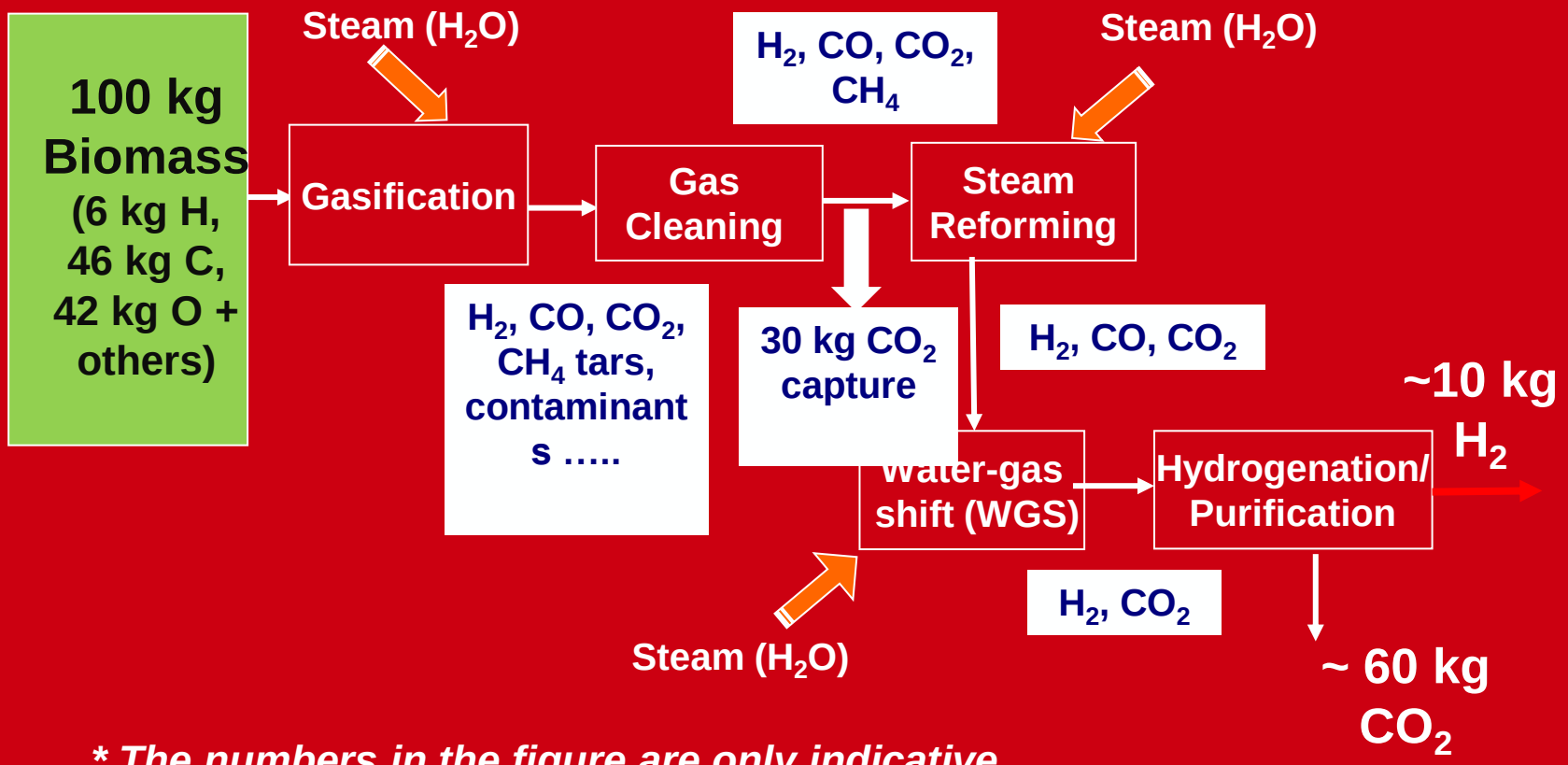
Associate Professor Mehdi Keyvan-Ekbatani (Civil Engineering)

- investigating green hydrogen's potential use in the transport sector, including for heavy-duty vehicles such as trucks and buses as well as trains, ships and aeroplanes.

H from woody biomass

Professor Shusheng Pang (Chemical and Process Engineering (CAPE) and his team have been working on experimental research to convert the wood biomass including pine trees, forest and wood process residues as well as forest slash, to green hydrogen

Schematic

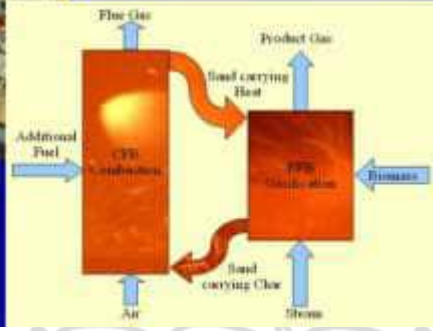


** The numbers in the figure are only indicative.*

The UC lab

The 100kW dual fluidized bed biomass gasifier in Chemical Engineering Department, University of Canterbury

- Challenges:
  - System is relatively complex thus suitable for scale above 20MW.
  - Value of the H_2 rich syngas should be fully explored.

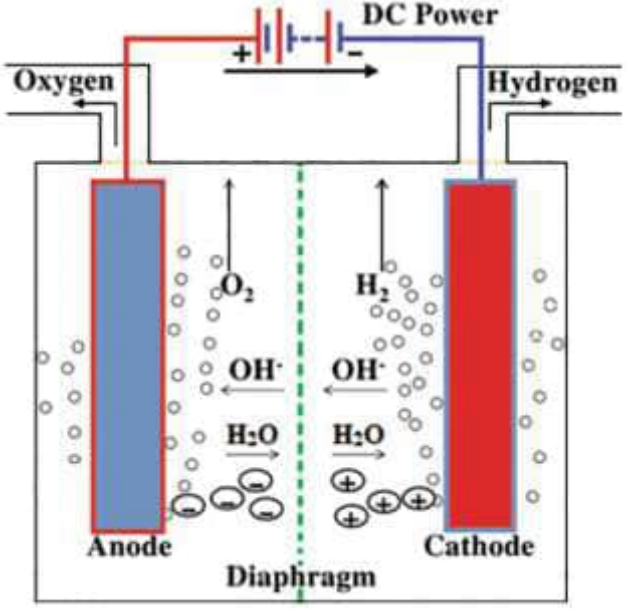


- Advantages of the technology:
  - High H_2 content in producer gas.
  - High heating values of the producer gas.
  - High efficiency.

A new type of water splitter

- Professor Aaron Marshall (Chemical and Process Engineering)is leading another Kiwi-German collaborative project that has been awarded $2 million funding over three years. The project's goal is to develop a new type of electrolyser – a tool that splits water into hydrogen and oxygen – to produce hydrogen energy in a more cost-effective way.

This will be achieved by increasing the efficiency of this well known process



https://www.canterbury.ac.nz/sustainability-hub/


Welcome
HAERE MAI
TO A STUNNING LAND & A GLOBAL
LEADER IN SUSTAINABILITY
CHRISTCHURCH
AIRPORT

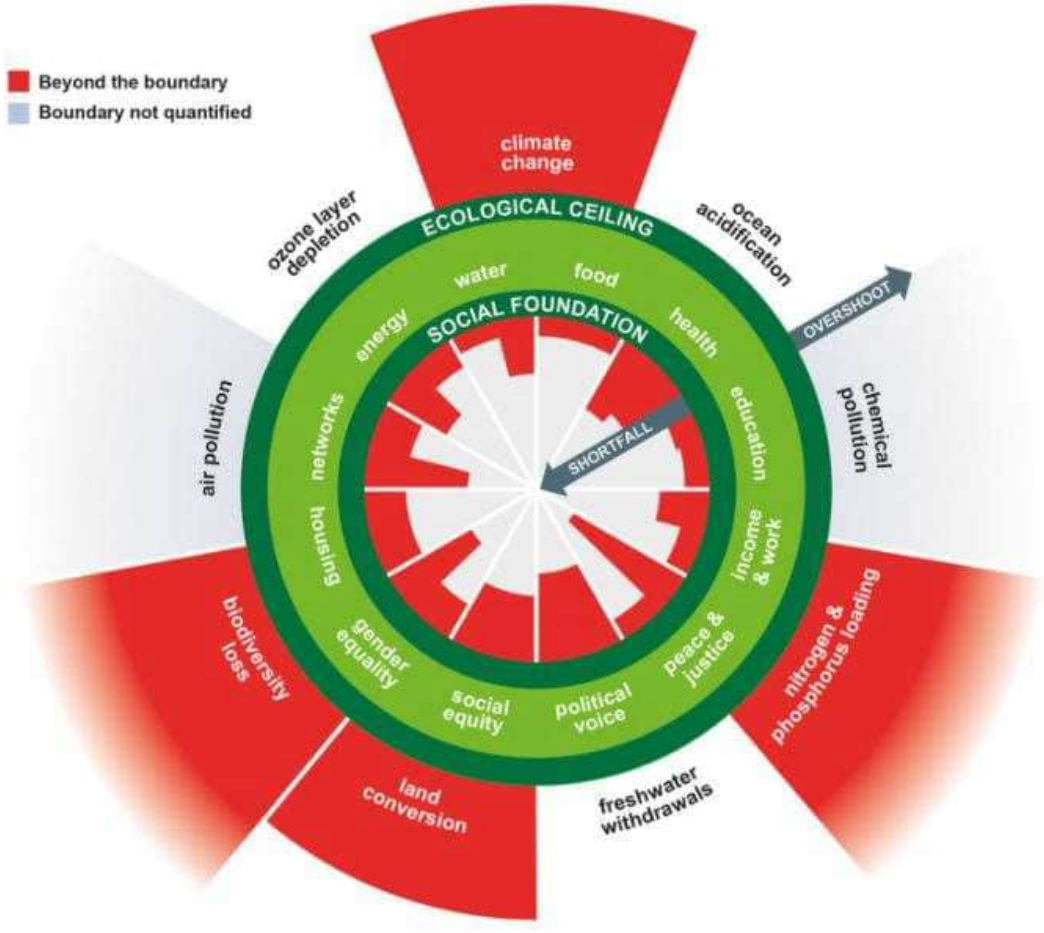


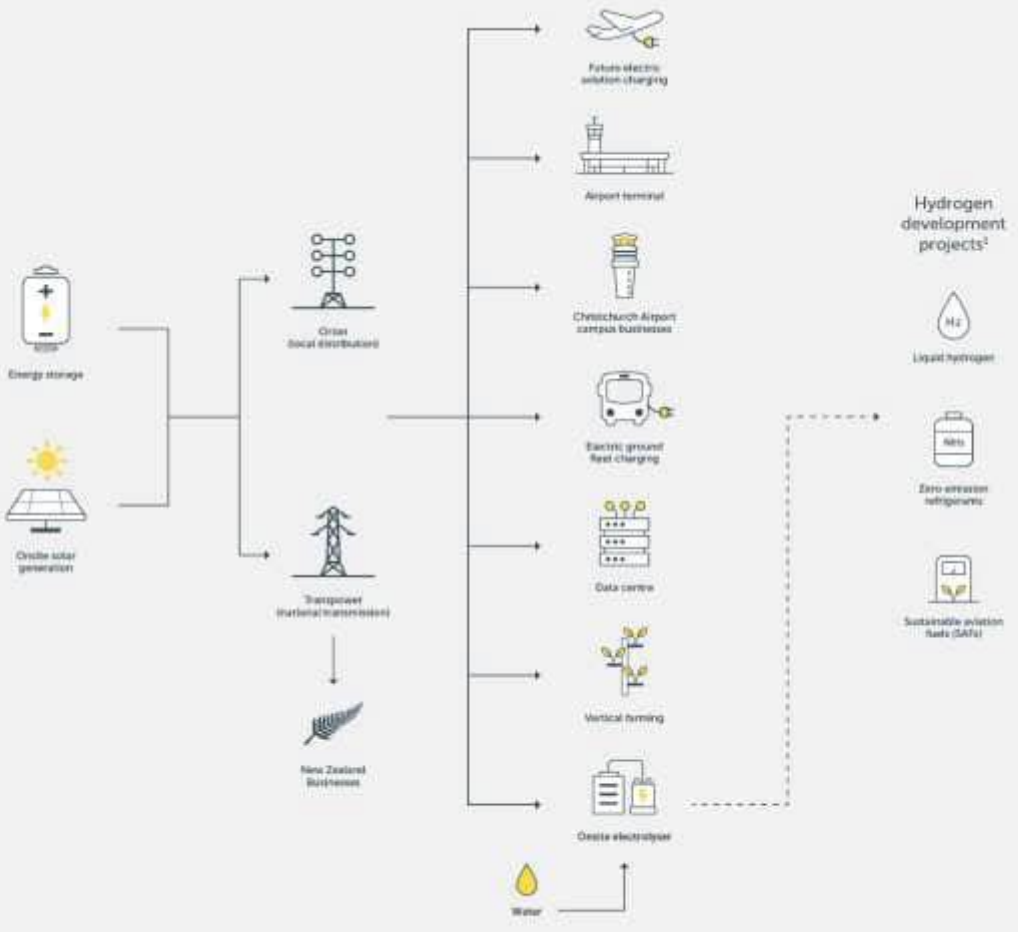
Image: Kate Raworth and Christian Guthier/The Lancet Planetary Health

Flight NZ0 Decarbonisation roadmap

	Sustainable Aviation Fuel	Zero Emissions Aircraft (ZEA)	Fleet Renewal	Operational Efficiency	Carbon Removals
Description	Non-fossil derived jet fuel, carbon reduction potential ~ 85%, compatible with existing aircraft without modification	Future hydrogen or battery or hybrid aircraft technologies	Rollover current fleet to new jets that achieve greater fuel efficiency	Optimising carbon efficiency from flight and ground operations	Credible carbon removal solutions aligned to international best practice
Decarbonisation Potential by 2050	↓ 50%	↓ 20%	↓ 20%	↓ <2%	Residual


The Hydrogen Consortium
Enabling zero emission aviation to take off in Aotearoa New Zealand
AIRBUS
AIR NEW ZEALAND
HIRINGA
FABRUM
AIRPORT
ZEROe
AIRBUS

Kōwhai Park Ecosystem 2050



Kōwhai Park

CHRISTCHURCH AIRPORT

Delivering renewable energy to enable aviation, land transport and other businesses to decarbonise

NOTE: 1. Hydrogen development projects will be customer led depending on the need of the offtakers

Aviation decarbonisation will be complex, and electricity is central

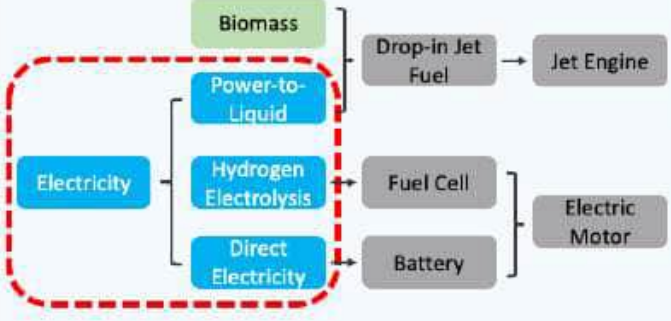
Aviation emitted 4.9 Mt CO_2 in 2019, equal to around 9% of NZ's net emissions. And, although air travel experienced a hiatus during COVID-19, it is already returning to pre-COVID levels with further expectations that global air travel will double by 2040. However, aviation is a challenging sector to decarbonise. NZ has poor alternative travel options given our geographical isolation. The physics of flight also present technical challenges to the use of batteries and hydrogen (H_2) gas.

However, the future is likely to see a mix of battery-powered, liquid H_2 and Sustainable Aviation Fuel (SAF) drop-in fuel replace traditional jet fuel. While some SAF can be made with biomass, competition for scarce land resources with other uses will limit its applicability as a feedstock.

Irrespective of the ultimate technology mix, the decarbonisation of aviation will significantly increase electricity demand. Many factors will determine the extent of the increase (e.g. economies of scale, technology readiness, network effects). Looking forward, aviation will be an important area to watch.

Pathways to net zero aviation

Almost all pathways involve increases in electricity demand



The potential demand growth from green hydrogen is enormous

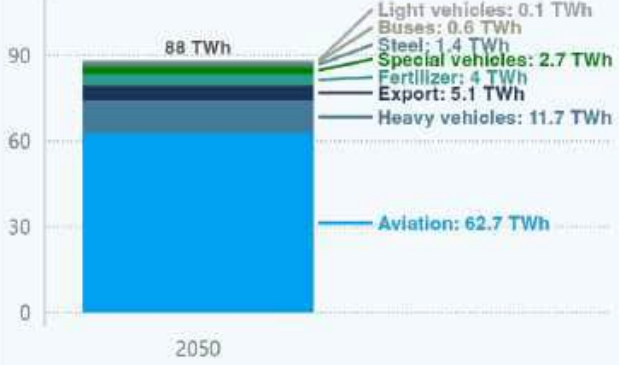
Our original WiTMH report in 2020 looked at electrification of the existing grid. Since then, the Government has started to focus on green hydrogen as one potential low carbon option to decarbonise our economy and export renewable energy.

MBIE recently published a report on hydrogen scenarios, which estimated the potential demand growth from key sectors in NZ. These estimates are subject to a wide range of uncertainty over factors such as technology splits in aviation and the price of both electricity and H_2 internationally and in NZ, and the technologies to store and transport H_2 at large scales.

The chart below illustrates the potential electricity demand that could result if all this H_2 was produced in NZ. In total, this amounts to over 88 TWh – for reference, the total national demand estimated in the *Accelerated Electrification* scenario was only ~70 TWh. The largest sector is aviation (71%), followed by heavy transport (13%) and fertilizer (4%). A further 6% could arise from export through initiatives like the Southern Green Hydrogen Project.

Potential green H_2 electricity demand

TWh, assuming 75% electrolysis efficiency



Kōwhai Park

Sustainably powering
future generations

FABRUM.

Application of Liquid Hydrogen in Aviation and Heavy Industry

Christopher Boyle

(Executive Chair)

FABRUM.

‘FABER’ (LATIN)

NOUN – ARCHITECT, CREATOR, MAKER

ADJECTIVE – SKILFUL, INGENIOUS

*‘**FABER** EST QUISUE FORTUNAE SUAE.”*

‘ EVERY MAN IS THE **MAKER** OF HIS OWN FORTUNE.’

SUPER CONDUCTING SYSTEMS

SAFRAN

magniX

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CONVERGENCE OF IP

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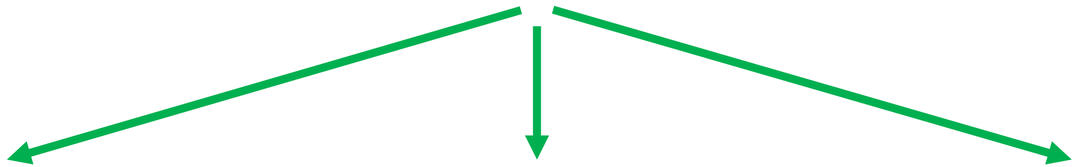

SUPER CONDUCTING SYSTEMS

- Electric Motors
- Transformers

TRADITIONAL CRYOGENICS

- Cryocooler Technology (LIN, LOX, LNG, LAIR)
- Cryo-Cube (distributed production)
- Helium-tight Cryogenic Storage

HYDROGEN/ LIQUID HYDROGEN (LH2)

- MFE Electrolysers
- <2 tpd LH2 Systems
- On-Board and Bulk LH2 Storage
- Ultra Fast LH2 Refuelling (30 -130 kg/min)

TRADITIONAL CRYOGENICS

Liquid Nitrogen – Animal breeding

Liquid Oxygen – Air Force

Liquid Nitrogen – Dark Matter

Liquid Air – Astronauts

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GREEN HYDROGEN

Heavy Transport

Mining

Aviation

MARKET LANDSCAPE

CENTRALISED PRODUCTION

- High CAPEX to build, long lead time to build.
- Offtake agreements required for financing.
- Hydrogen gas is needed to be compressed or liquified for transportation to point of use.
- Transportation and distribution beyond the point of production are inefficient.

DECENTRALISED PRODUCTION

- ✓ Low CAPEX to build with ease of adding more 1 or 2 MW containerised modules as demand grows.
- ✓ Hydrogen can be produced on-site with liquefaction and a refuelling station.

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ONSITE HYDROGEN PRODUCTION

- Membrane Free Electrolysers
- 1.1 MW ~ 451 kg (gas)/day
- Cryogenic Separation of H_2 and O_2
- 99.999% H_2 and 99.8% O_2
- 25 years stack life
- No need for ultra pure water
- Water reject 2-3%
- Ease of liquefaction

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INDUSTRY APPLICATIONS

HEAVY TRANSPORT AND INDUSTRY

END TO END PROCESS SOLUTION

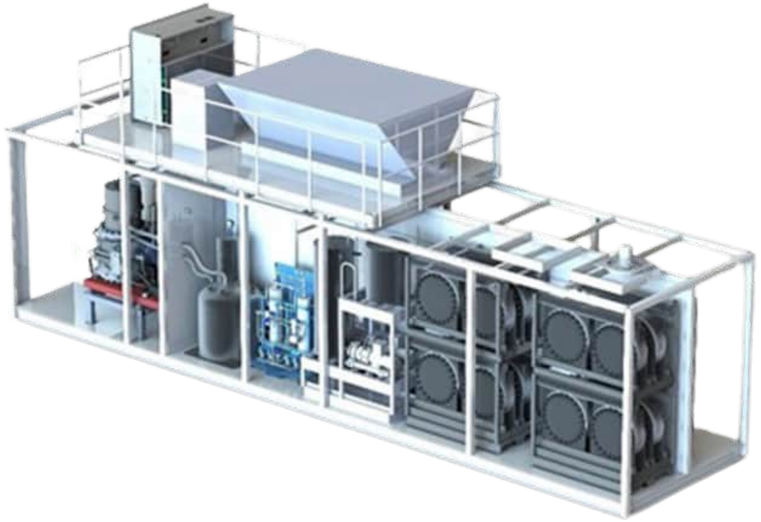
Zero-emission Experts Fabrum Partner With HWR To Decarbonise Its Transport Fleet With Hydrogen

Monday, 11 July 2022, 7:32 pm
Press Release: Fabrum

Buses 20-30 kgs / d

Trucks 8Kg/100km

BIOWASTE TREATMENT PLANT



HYDROGEN

OXYGEN
PROCESS HEAT

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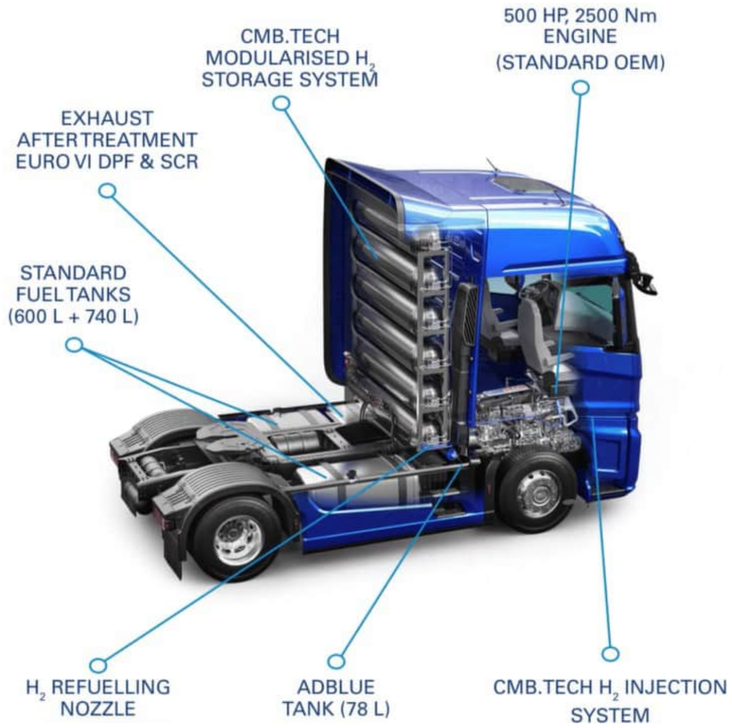
INDUSTRY APPLICATIONS

FIRST DUAL FUEL TRUCK IN SOUTH!



HWR DUAL FUEL HYDROGEN TRUCK

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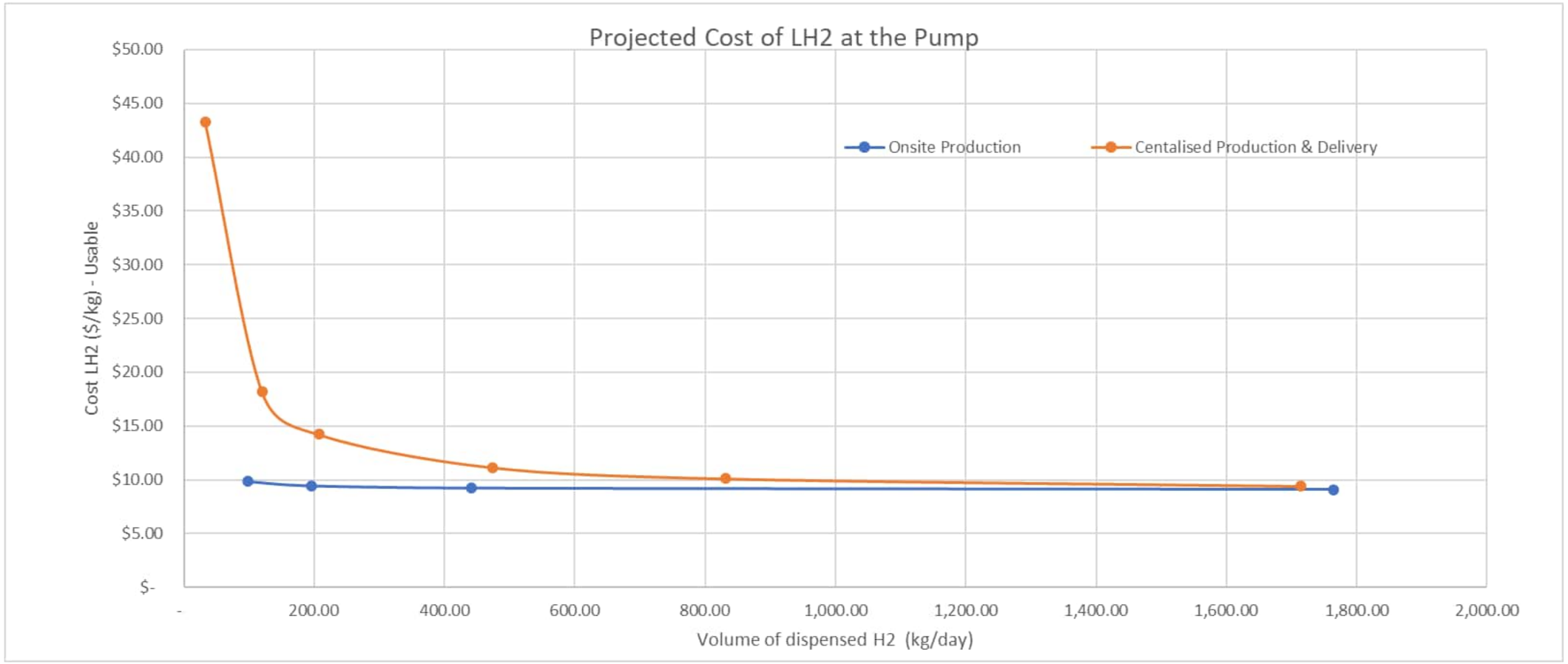
LIQUID HYDROGEN

'Modular units inclusive of electrolysis, liquefaction, bulk storage, and dispensing would enable earlier adoption of LH2 and, further, enable remote regions further from central fuelling depots to be serviced by fleets using LH2.'



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DISTRIBUTED LIQUEFACTION (<2 TPD)

10-50kg/day, Aviation testing

No Nitrogen pre-cooling required!

500kg/day, Mining application

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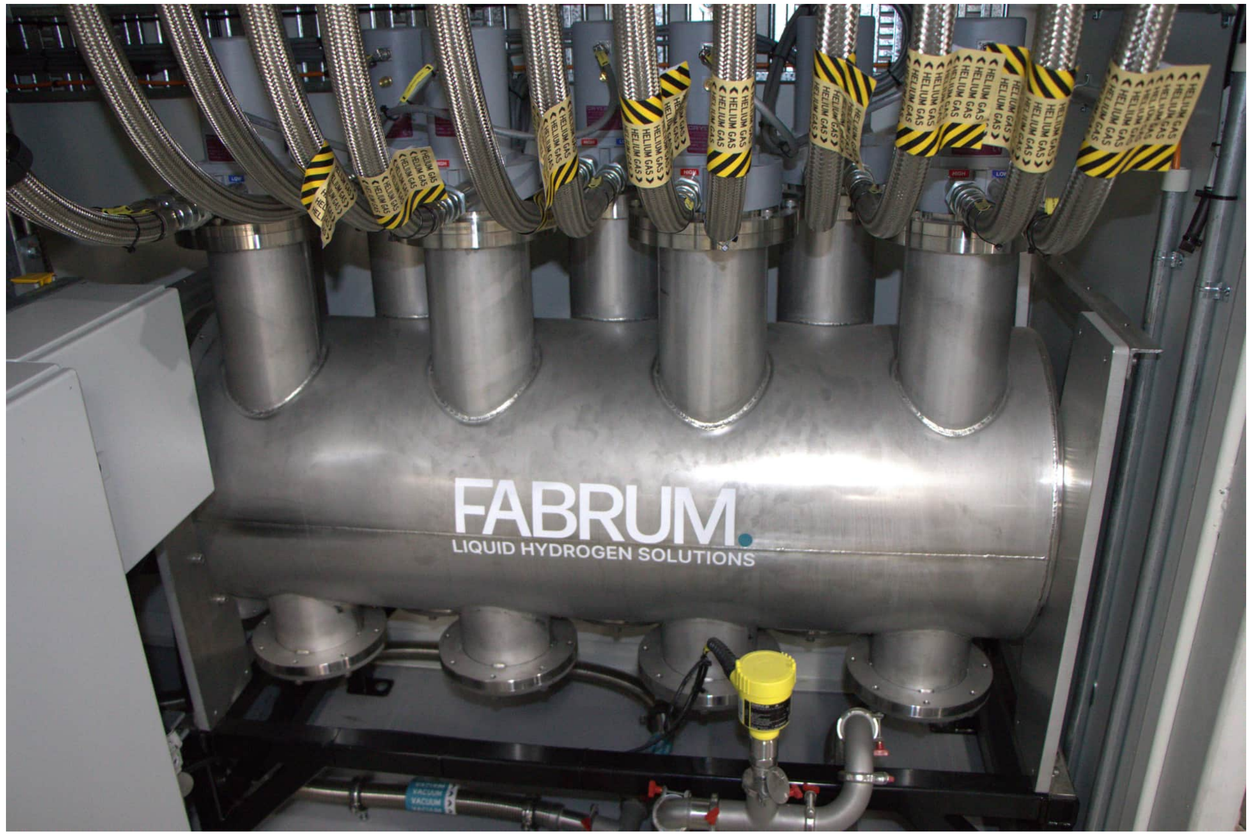
2-STAGE, MODULAR HYDROGEN LIQUEFACTION

FABRUM cryocoolers provide a powerful **1st stage** to 60K



We use three options for 2nd stage
(Application dependent)

GM Cold Heads
- Efficient
- Able to turn down effectively
- Suitable for smaller systems 0-500kg/day

Joule-Thomson
- High reliability
- Low capital cost, but less able to vary output
- Good power efficiency
- Suitable for 250-1000kg /day

Turbo-Brayton
- Good power efficiency
- Suitable for 500-1000 kg/day

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BOIL OFF GAS MANAGEMENT SYSTEM (LH2)

FABRUM cryocoolers are being used for BOGM

- Industrialised and Robust
- 100kg per day per PTC1000
- Easy to integrate
- Available for LIN, LOX, LNG, LH2
- Reliable
- Low maintenance

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LH2 STORAGE

- Zero Boil Off!
- Patented technology enables fast filling with 70% reduction in boil off
- >30% gravimetric capacity compared to traditional metal tanks

On-Board LH2 tanks for Mobility

Undergoing aviation certification

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HEAVY INDUSTRY DECARBONIZATION

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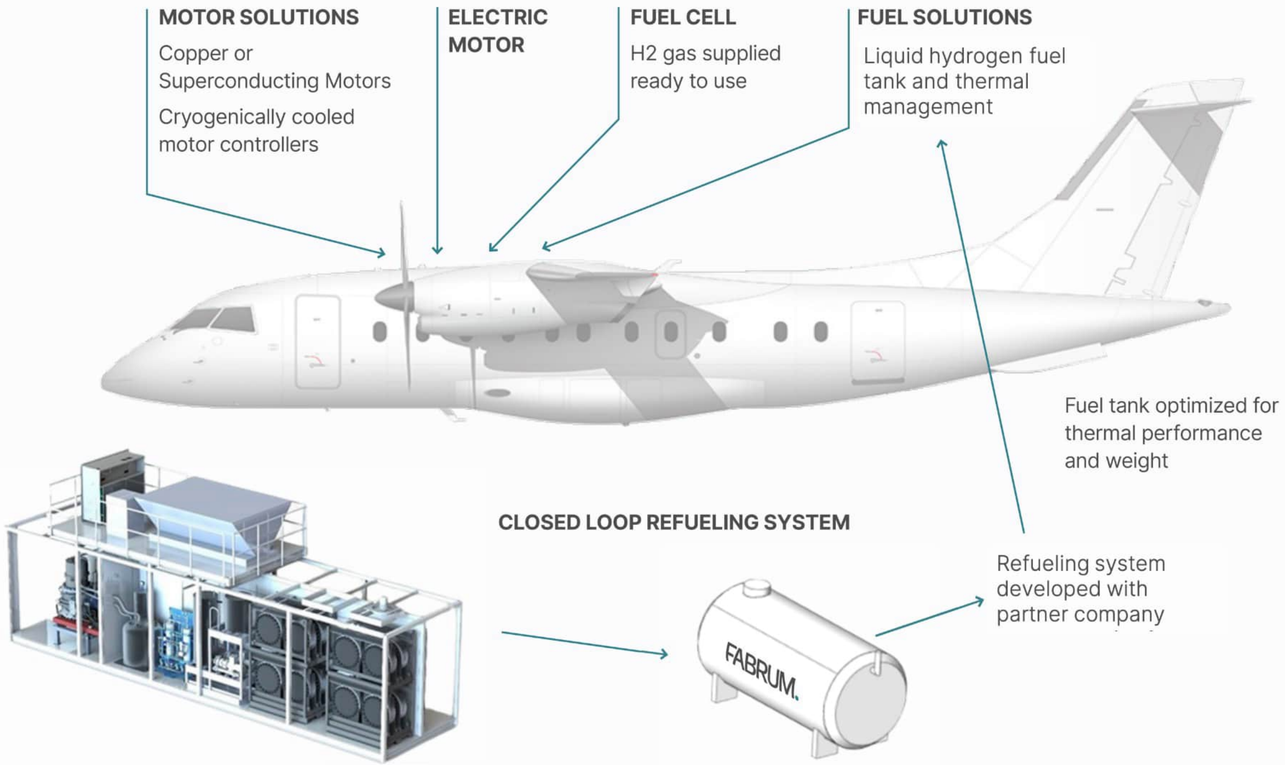
LH2 IN AVIATION

AIR NEW ZEALAND FABRUM. HIRINGA

CHRISTCHURCH AIRPORT AIRBUS FORTESCUE FUTURE INDUSTRIES



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INDUSTRY APPLICATIONS

MARINE

HYDROGEN POWERED ETNZ CHASE BOATS

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