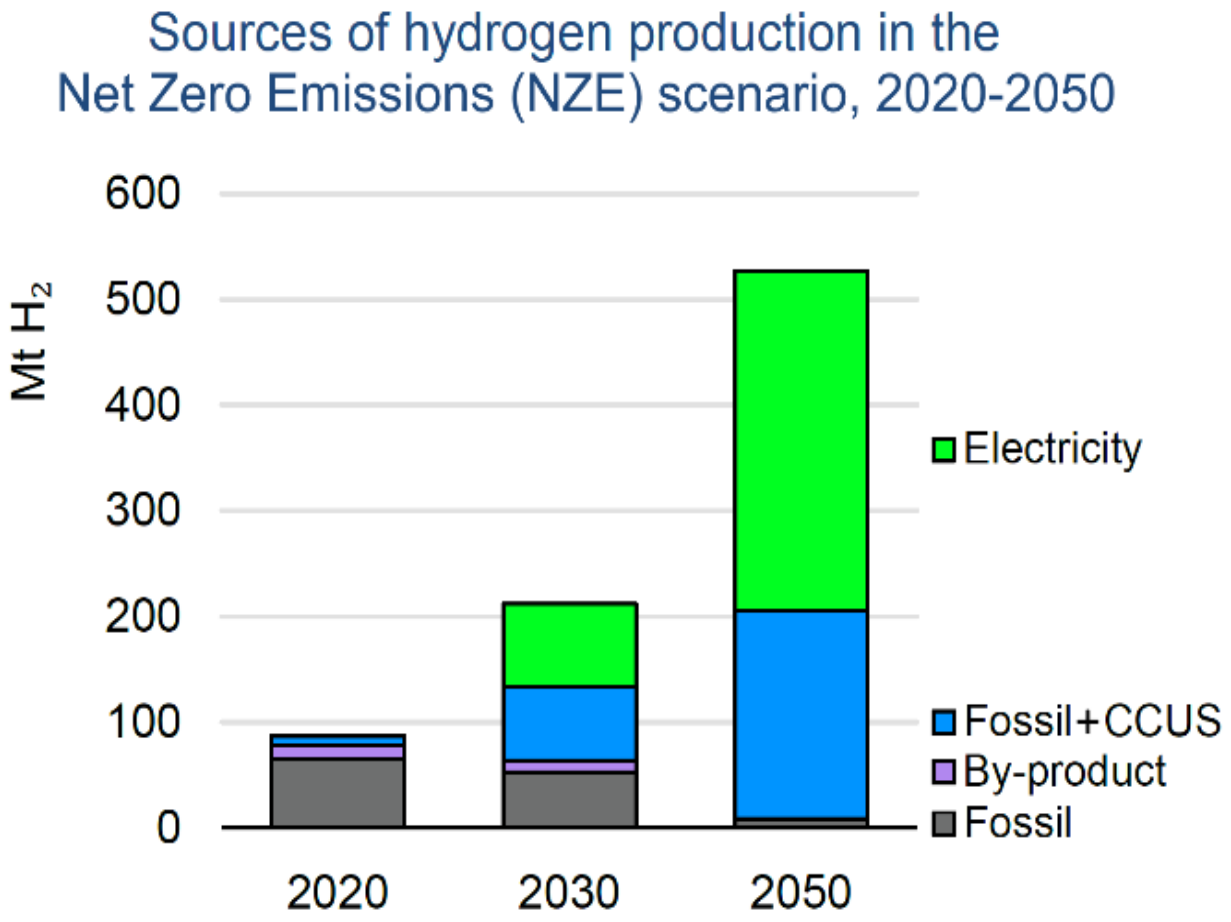
German-New Zealand green hydrogen alliance

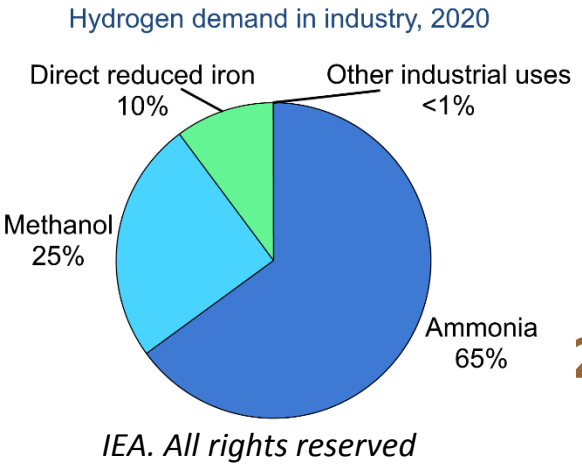
Professor Sally Brooker

University of Otago; sbrooker@chemistry.otago.ac.nz

NZ Hydrogen Council networking event and AGM, Hyundai Auckland, 8 Sept 2022

Global industrial production & use of H_2



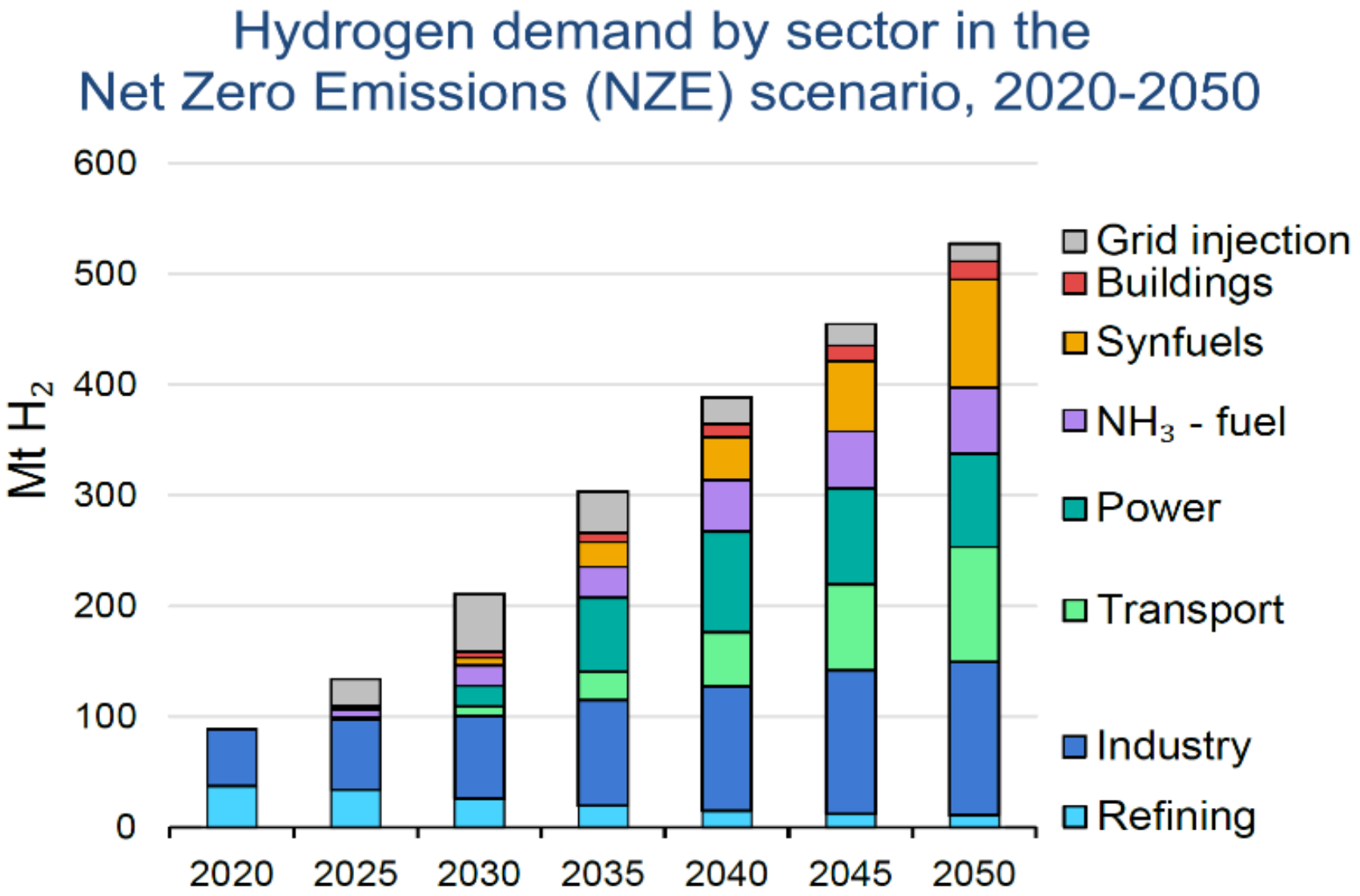


2020: 90 million tons pa; 98+% 'brown' hydrogen

2050: 530 million tons pa? 99% green or blue?

https://www.iea.org/reports/global-hydrogen-review-2021

Global industrial production & use of H_2



https://www.iea.org/reports/global-hydrogen-review-2021

Grants for **German-NZ Green H_2 networking, outreach & research centre**

Prof Sally Brooker (Otago) leading 'team NZ' & Dr **Paul Jerabek** (Helmholtz Zentrum Hereon) is German lead

> 270 contacts to date in this growing network of research and industry partners across NZ and Germany

Iwi, MacDiarmid,
Unis, CRIs, NZ H_2 Council
Callaghan Innovation,
Polytechs, Ara Ake,
businesses…

CATALYST FUND

Bundesministerium für Bildung und Forschung

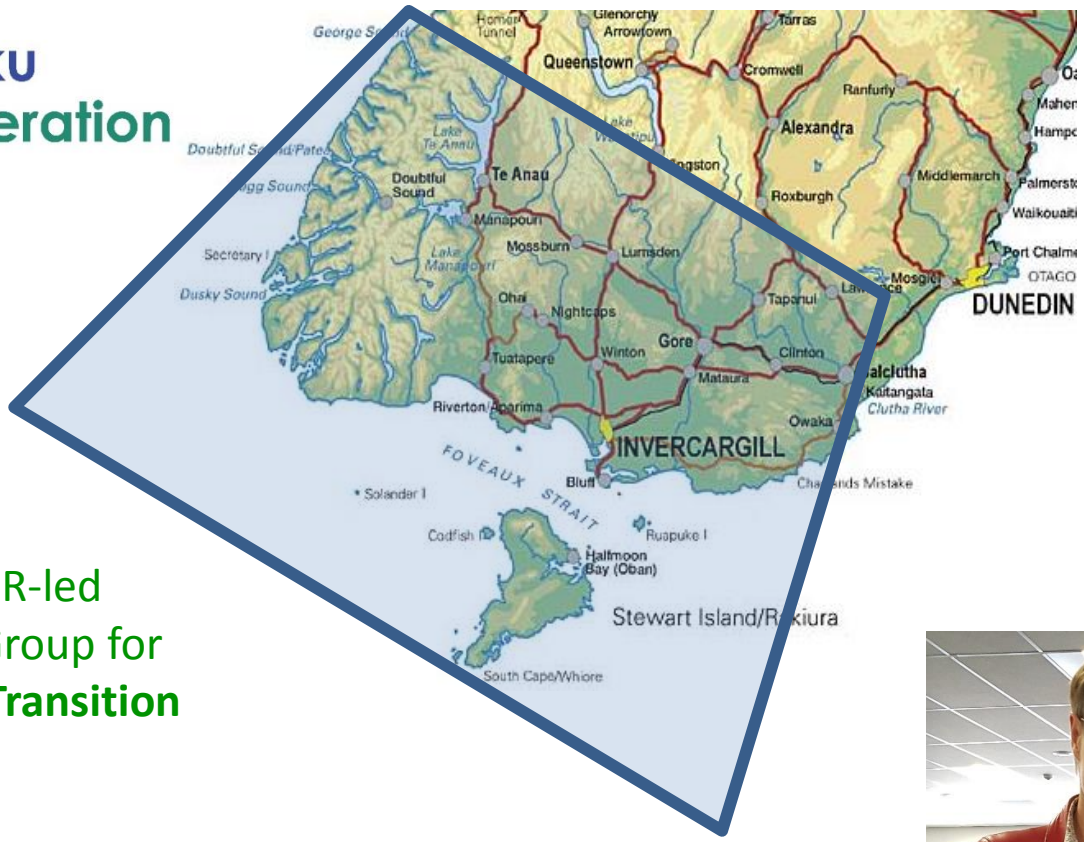
2021-2026

Partnership with Ngāi Tahu

Ngāi Tahu and MR have both hosted us at wānanga; more planned for this year (Otago+Canty)

Our four Murihiku Papatipu Rūnanga are individually strong, collectively enabled and driving Rūnanga and regional aspirations that will sustain our lifestyles in a thriving, healthy environment for our generations to come.

Murihiku Regeneration



Ngāi Tahu + MR
Sir Tipene O'Regan
Aimee Kaio

Member of the MR-led
Energy Working Group for
Southland's Just Transition

Nzer of year 2022

Te Rūnanga o NGĀI TAHU

Grants for **German-NZ Green H_2 networking, outreach & research centre**

Prof Sally Brooker (Otago) leading 'team NZ' & Dr **Paul Jerabek** (Helmholz Zentrum Hereon) is German lead

> 270 contacts to date in this growing network of research and industry partners across NZ and Germany

Well configured lab & office (Chemistry, Otago) in which the **German-NZ Green Hydrogen Centre** will be located, alongside Chemistry Outreach team and Dr Anna Garden's catalyst modellers

Grants for German-NZ Green H_2 networking, outreach & research centre

Prof Sally Brooker (Otago) leading 'team NZ' & Dr **Paul Jerabek** (Helmholz Zentrum Hereon) is German lead

> 270 contacts to date in this growing network of research and industry partners across NZ and Germany

Glovebox

Arc melter

Planetary ball mill

Sievert apparatus

custom build by **HZH**

New capability in NZ (**A/Prof Nigel Lucas**, Otago) Sieverts enables accurate measurement of H_2 uptake by storage materials under wide range of P & T

UNIVERSITY of OTAGO
Te Whare Wānanga o Otāgo
NEW ZEALAND
SAPERE AUDE

Helmholtz-Zentrum hereon

CATALYST FUND

Bundesministerium für Bildung und Forschung

Green Hydrogen Outreach

Visits brilliantly MC'ed by **Ra Dallas** (nkmp) for Murihiku Regeneration, with activities led by **Dr Dave Warren** (Otago University) and his outreach team, accompanied by Hamish Tonkin (GWD Motor Group) with the Hyundai Nexo

7x Invercargill Schools visits Nov 2022
associated with the Murihiku Regeneration wananga - and the Nexo they organized ☺

Southland Girls High School

Te Whare Kura o Arowhenua

Hope and actions (angst re climate change)
Educate & encourage students into careers in STEM
Future workforce
Leave no one behind in E-transition

German-NZ green H_2: Industry Connections ↔ Southern Innovation Campus

CITYLAB DESIGN / TRANSPORTATION / ENVIRONMENT / EQUITY / LIFE

"Lower Saxony (Germany) plans to bring a further 14 hydrogen trains into service by the end of 2021 at a cost of €81 million"

Alstom

Germany Has the World's First Hydrogen-Powered Passenger Train

FEARGUS O'SULLIVAN SEP 26, 2016

https://www.businessinsider.com.au/airbus-hydrogen-powered-airplane-photos-details-2020-9?r=US&IR=T

Hiringa and Hyzon: NZ first 4 H_2 fuel stations and 20 H_2 trucks in 2022

https://www.stuff.co.nz/motoring/122636171/zeroemission-hydrogen-heavy-trucks-to-hit-kiwi-roads

H2 or dual fuel options for **farmers** tractors, harvesters, etc

NZ is innovative, has skilled workforce, & can be fast on its feet (e.g. Rocket Lab; **Emirates Team NZ foiling H2 chase boats**) - lets accelerate this – early bird catches the economic & environmental worm ☺

Industry networking e.g. future fuels in aviation

Cannot directly electrify!

Small short haul =
battery electric (zero-e)

Medium haul (domestic)
= **hydrogen (zero-e)**

ElectricAir zero-e crossed Cook Strait 1Nov2021

https://www.businessinsider.com.au/airbus-hydrogen-powered-airplane-photos-details-2020-9?r=US&IR=T

Airbus zero-emission electric and H_2 planes by 2035

Long haul = SAFs (sustainable aviation fuels) = 'drop in' (liquid) biofuels/synfuels (at best **carbon-neutral**)

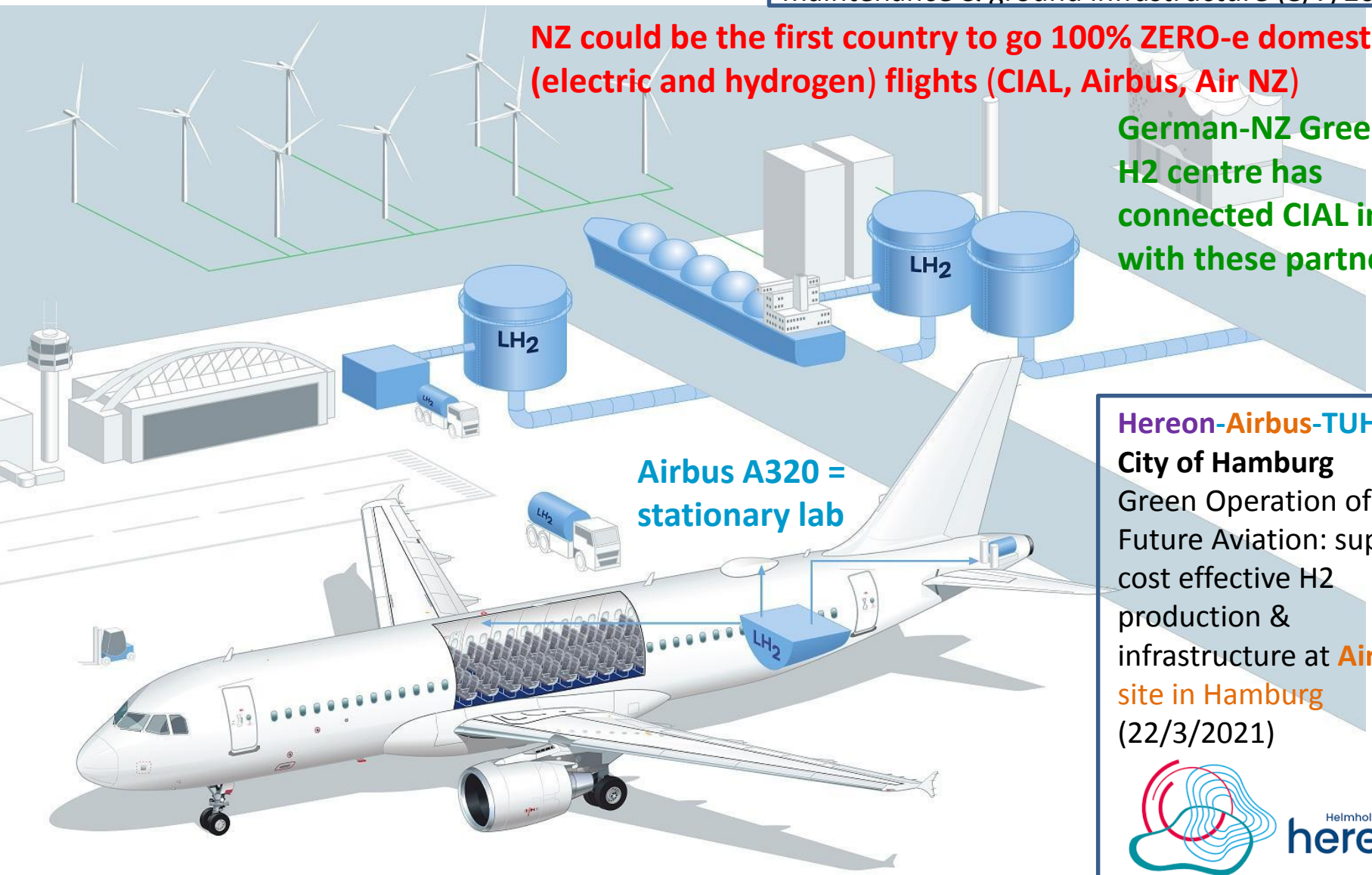
ODT article celebrating **MOU signed by Air NZ and Airbus** to investigate the **future of hydrogen planes in NZ**

Hamburg = worlds 3rd largest civil aviation location

Hamburg Airport, DLR, Lufthansa, ZAL H_2 demo – H2 demonstration of aircraft maintenance & ground infrastructure (8/7/2021)

NZ could be the first country to go 100% ZERO-e domestic (electric and hydrogen) flights (CIAL, Airbus, Air NZ)

German-NZ Green H2 centre has connected CIAL in with these partners



Airbus A320 = stationary lab

Hereon-Airbus-TUHH-City of Hamburg Green Operation of Future Aviation: supply cost effective H2 production & infrastructure at Airbus site in Hamburg (22/3/2021)

Helmholtz-Zentrum hereon

https://www.hereon.de/innovation_transfer/communication_media/news/099910/index.php.en

https://marketing.hamburg.de/aktuelle-pressemeldungen-detailansicht-221/research-project-for-the-use-of-hydrogen-in-aviation-starts-in-hamburg.html

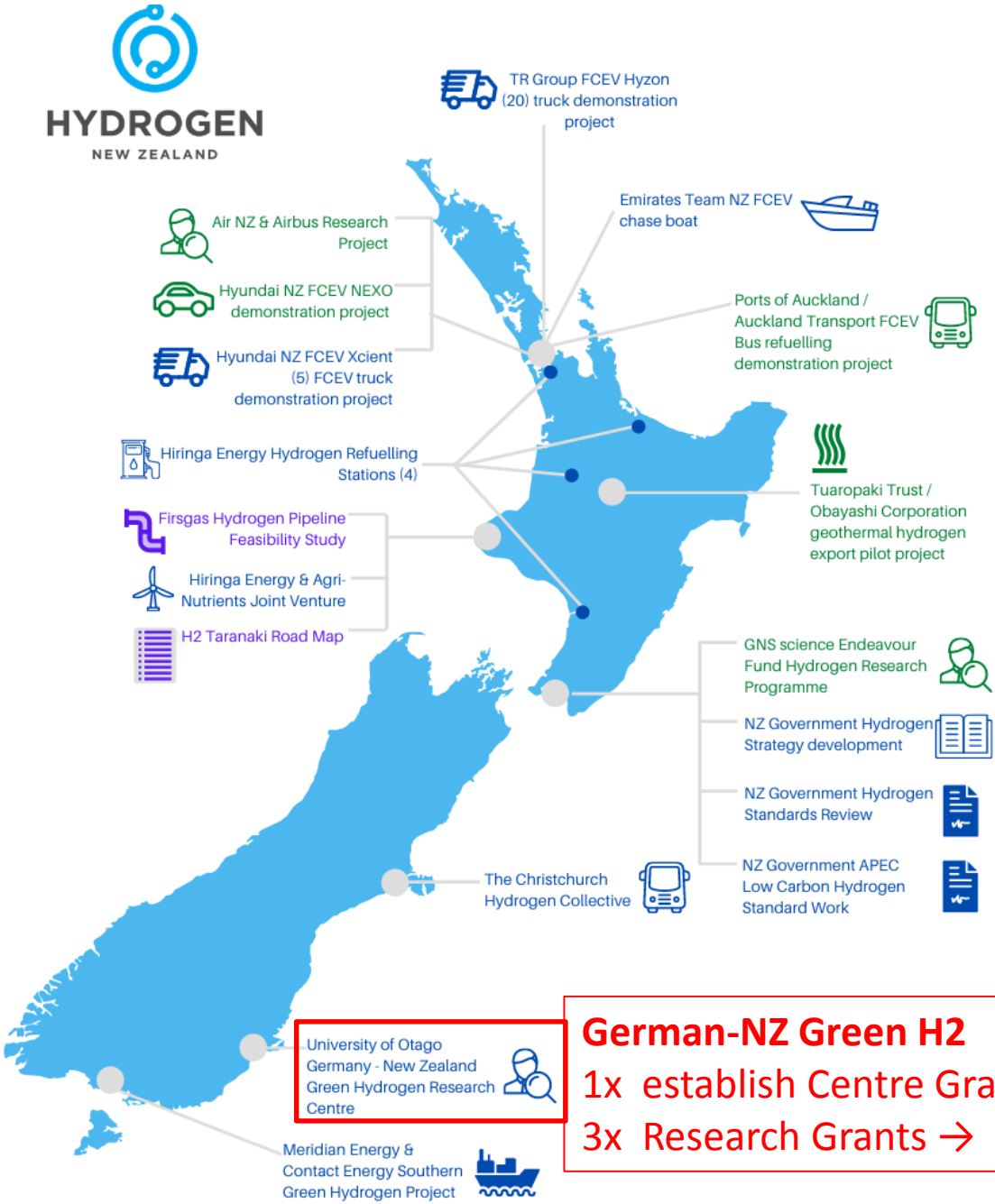
https://www.dlr.de/content/en/articles/news/2021/03/2021082021_maintenance-and-ground-processes-for-future-aircraft-generations.html

NZ Hydrogen Council

Critical overarching body

Encourage all businesses and research organisations in the field to join up

1st NZ hydrogen symposium, 1-3 Feb 2023, University of Otago (organising committee Brooker, Garden, Kaio, Marshall, Peer, Haas with Jerabek and NZ H2 Council) is research focussed, whilst the **H2Zero Summits** will continue to be industry/policy focussed -- but each with a taste of the other – both will be annual events

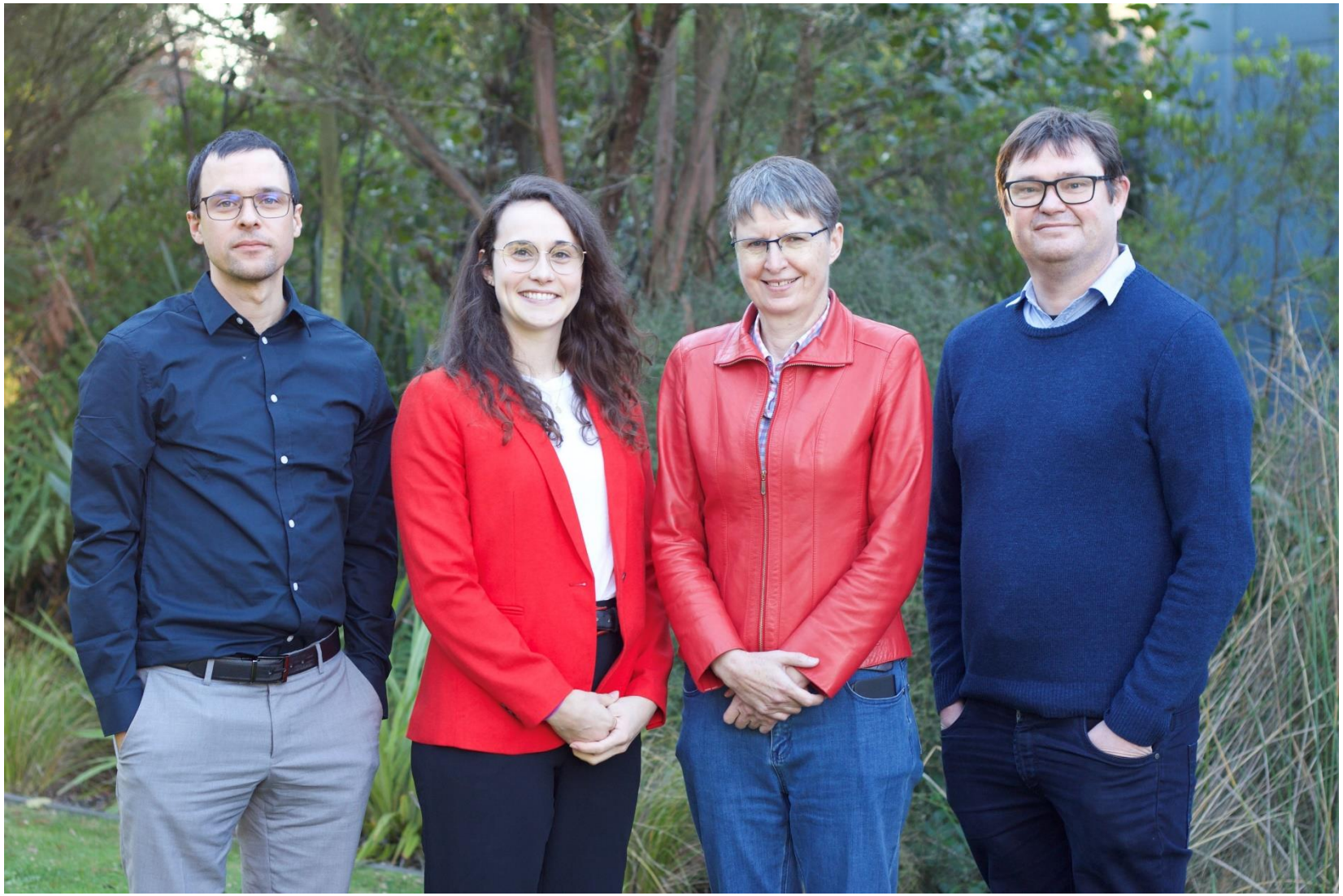


German-NZ Green H2

1x establish Centre Grant

3x Research Grants →

3 successful German-NZ green hydrogen research grants (2022-2025):



On the NZ-side led by: **Drs Jannik Haas and Rebecca Peer** (Civil Engineering, Canterbury); **Professor Sally Brooker** (Chemistry, Otago); **Professor Aaron Marshall** (CAPE, Canterbury)

3 German-NZ green H2 research grants (each $2Mill on the NZ side):

"Safe, low cost, hydrogen storage materials from NZ resources"

Professor Sally Brooker (Chem, Otago) and Dr Paul Jerabek (Institute for Hydrogen Technologies, Helmholtz Zentrum hereon) with Aimee Kaio (Ngāi Tahu, Awarua), Dr Linda Wright (NZ H2 Council), A/Prof Nigel Lucas (Otago), Dr Anna Garden (Otago), A/Prof Michael Jack (Otago), A/Prof Jonathan Leaver (Unitec), Dr Chris Bumby (RRI, Vic), A/Prof Alex Yip (Canterbury) and Prof Peng Cao (Auckland) in NZ; and the German team from HZH includes Drs Klaus Taube, Claudio Pistidda, Lars Baetche, Julian Puszkiel, Thomas Klassen; plus 5 PhD and 3 Masters candidates; plus industry partners.

"Investigating ways of producing low-cost green hydrogen"

Prof Aaron Marshall (Chem Process Eng, Canterbury) with Prof Daniel Holland (Canty), A/Prof Geoff Waterhouse (Auckland), Dr Kim McKelvey (Victoria) in NZ; and the German team includes Dr Christian Immanuel Bernäcker (**Fraunhofer Institute for Manufacturing Technology and Advanced Materials**) and Prof Christina Roth (**Universität Bayreuth**); plus postdocs and 3 PhD candidates.

"Creation of a NZ-German platform for green hydrogen integration"

Drs Jannik Haas and Rebecca Peer (Civil Eng, Canterbury) with Philpott, Gils, Wood, Medjroubi, Keyvan, Logan, Downward (Auckland and **DLR**), and 6 PhD candidates.

“Safe, low cost, hydrogen storage materials from NZ resources”


Prof Sally Brooker

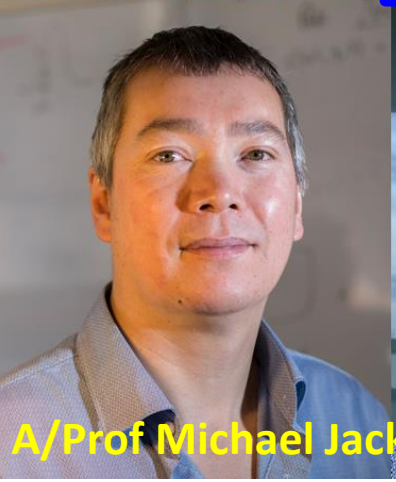

Dr Paul Jerabek

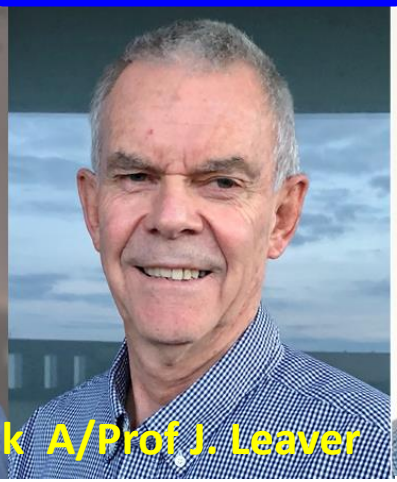

Aimee Kaio


A/Prof Nigel Lucas

& Dr Linda Wright (not shown)


Dr Anna Garden


A/Prof Michael Jack


A/Prof J. Leaver


Dr Chris Bumby


A/Prof Alex Yip


Prof Peng Cao

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NEW ZEALAND

Helmholtz-Zentrum hereon

Te Rūnanga o NGĀI TAHU

CATALYST FUND

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Unitec NEW ZEALAND
Te Whare Wānanga o Wairaka

VICTORIA UNIVERSITY OF WELLINGTON
TE HERENGA WAKA

UC UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha

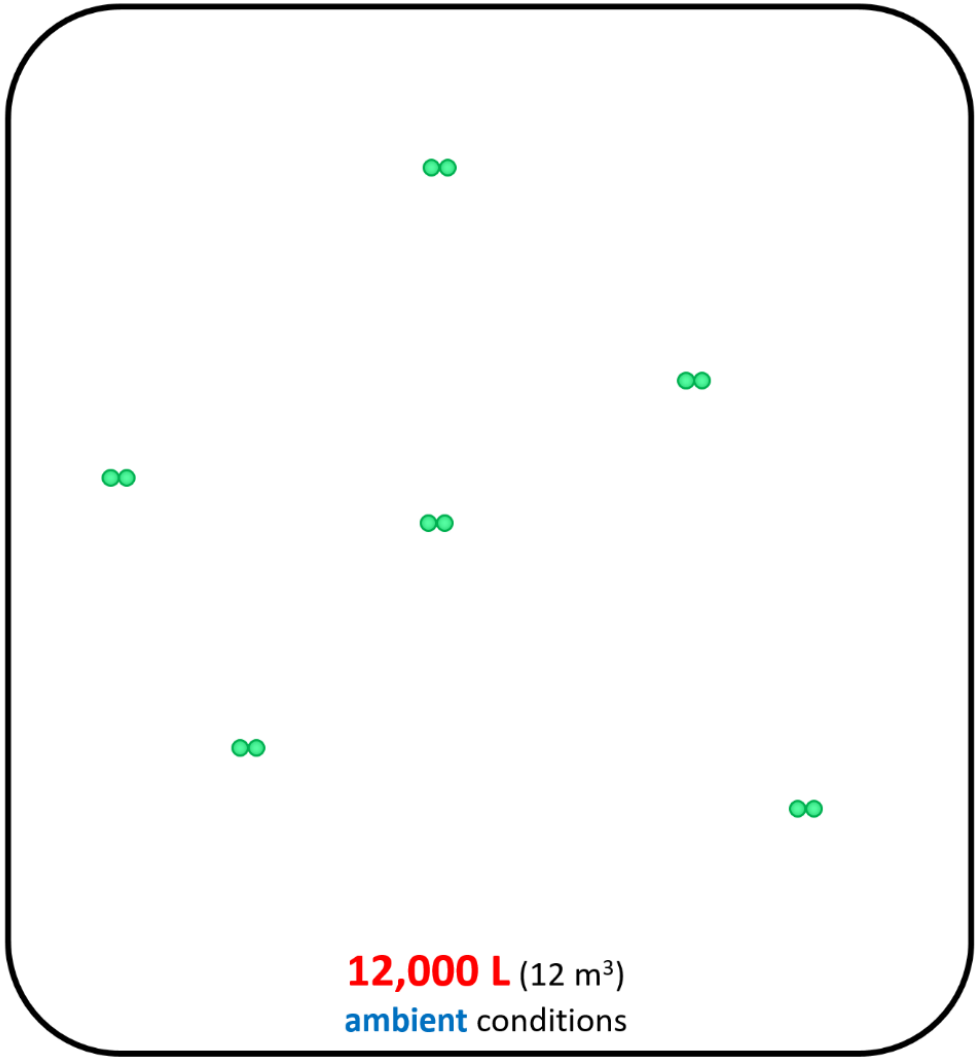
THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

Te Mana Tangata Whakawhanake
MacDiarmid Institute
Advanced Materials & Nanotechnology

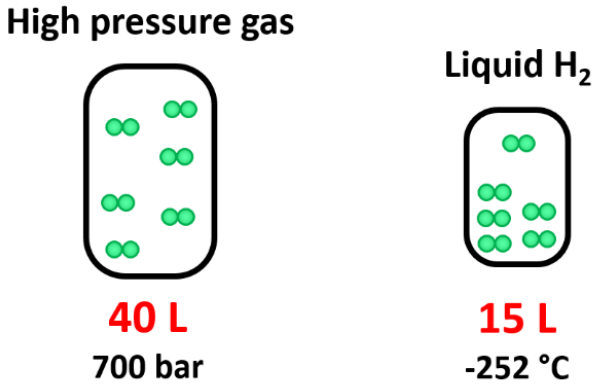
HYDROGEN
NEW ZEALAND

Safe, low cost, hydrogen storage materials from NZ resources

Our **NZ-wide team** (previous photo) with our **Helmholtz Zentrum Hereon** collaborators and our **5 PhD and 3 Masters students** plus **NZ and German industry partners** are targeting:



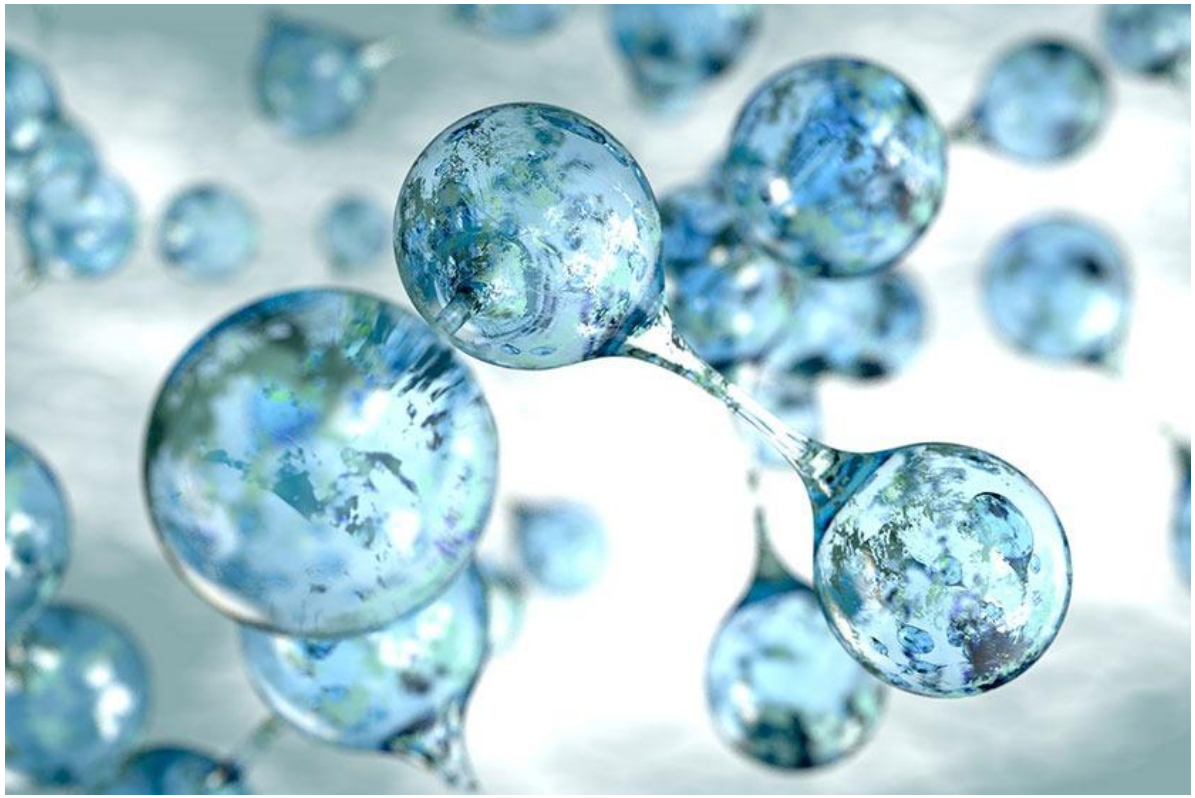
Storage Cylinder Sizes for 1 Kg of Hydrogen



German Government green H_2 initiatives:

Addressing chicken↔egg problem: invested Euro900million in **H2Global**, a green hydrogen (and its derivatives) purchasing instrument (10 year contracts), expected to initially run at a loss which the German Govt will cover for a max of 10 years

https://www.bmwi.de/Redaktion/EN/Pressemitteilungen/2021/12/20211223-900-million-euro-for-h2global-hydrogen-project.html



Previously:

Jan 2020: €700million on 3 big team H2 research projects running 2021-2025

10June2020 German National Hydrogen Strategy published

Nearly €10 billion ($16.4 billion) of Germany's coronavirus stimulus package has been earmarked for the development of a domestic hydrogen industry and building international supply chains… Germany had identified a hydrogen demand of about 1000 TWh per year by 2030, which is equivalent to about 3 million tonnes… 15% [made] domestically [rest] imported…

EU: €300.5million matched funding 50:50 with clean H2 industry…

German-NZ Green H_2 networking, outreach & research centre (BMBF-APRA)

Sally Brooker *(Otago) leading 'team NZ' &* ***Paul Jerabek*** *(Helmholz Zentrum Hereon) is German lead*

Companies include: Airbus, Hamburg airport, CIAL, Air NZ, Meridian, Contact, FFI, Fabrum, Hiringa, Firstgas, PowerCo, H2X, NZIMMR, Ballance, GoodNature, GBV… plus: Enapter, GKN, Siemens Energy, Sunfire, GP Joule, Intelligent Energy…

Helmholtz-Zentrum hereon

1st NZ Green hydrogen conference, 1-3 Feb 2023, University of Otago; organising committee Brooker, Garden, Kaio, Marshall, Peer, Haas, Kennedy, Waterhouse, NZ H_2 Council

CATALYST FUND

Bundesministerium für Bildung und Forschung

1x Centre & 3x Research grants

Approx NZD 10 Mill into German-NZ green H_2

https://events.otago.ac.nz/2023-nz-hydrogen-symposium/

University of Otago
Te Whare Wānanga o Otāgo
New Zealand

Te Mana Tangata Whakawhanake
MacDiarmid Institute
Advanced Materials & Nanotechnology

Abstracts website upload by **Friday 2 Dec**
Early bird registration before **Monday 12 Dec**
Co-chairs: Brooker, Garden, Jerabek
NZ organising committee: Kaio, Marshall, Peer, Haas, Kennedy, Waterhouse, NZ H_2 Council

CATALYST FUND

Bundesministerium
für Bildung
und Forschung

Confirmed speakers to date:

Dr Paul Jerabek (Helmholtz Zentrum Hereon)

Prof Christina Roth (University of Bayreuth, Germany)

Prof Smaranda Marinescu (University of Southern California, USA)

Prof Rodrigo Palma-Behnke (Director Energy Center, University of Chile)

Prof Pierluigi Mancarella (Chair Power Systems, University of Melbourne, Australia)

Prof Zhenguo Huang (University of Technology Sydney, Australia)

Prof Jillian Dempsey (University of North Carolina Chapel Hill, USA)

Dr Christian Immanuel Bernäcker (Fraunhofer IFAM, University of Würzburg, Germany)

Dr Klaus Taube (Helmholtz-Zentrum Hereon, Germany)

Sir Tipene O'Regan and Hana O'Regan (Awarua Runaka and Te Rūnanga o Ngāi Tahu)

Terry Nicholas (Murihiku Regeneration and Te Rūnanga o Ngāi Tahu)

Dr Linda Wright (NZ Hydrogen Council)

Dr Abbi Virens (Centre Sustainability, Otago) "Social Dimensions and Anticipations of Green Hydrogen in NZ"

Dr Luke Liu (Victoria University) "Covalent organic frameworks for H_2 storage? – A computational perspective"

Dr Mila Adam (School Environment, Auckland) "Pūhiko Nukutū: A Green H_2 Geostorage Battery in Taranaki"

Assoc. Prof. Fei Yang (Waikato) "Novel High Entropy Alloys for Green H_2 Production and Storage Applications"

Christopher Boyle / Ojas Mahapatra (Fabrum) - Membrane-less electrolyser and liquid hydrogen production

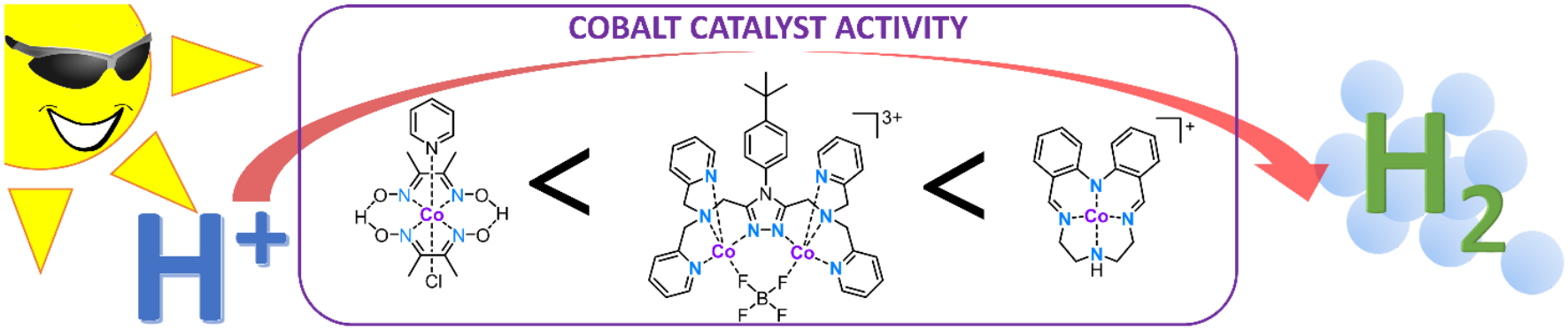
Sam Powick (Hiringa) - Hydrogen refuelling stations in NZ

1st New Zealand Hydrogen Symposium
University of Otago
1–3 February 2023

My interests: molecular catalysts for future fuels:

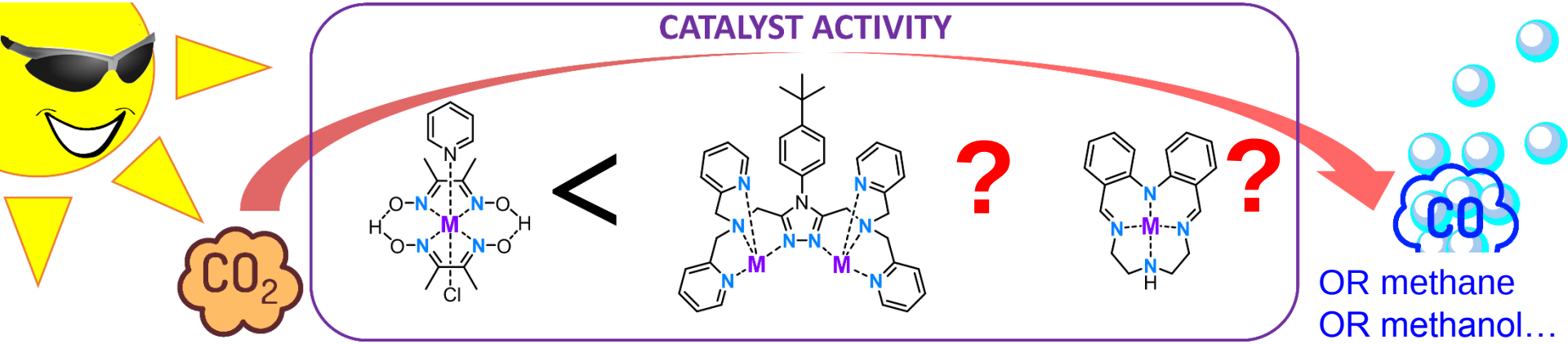
Photocatalytic hydrogen: Co complex activity 2-3x greater than lit. std. – aim for even better!

Electrocatalytic hydrogen: Cu complex has high and long lived activity in water ☺ ☺



- **R.W. Hogue**, O. Schott, **G.S. Hanan**, **S. Brooker**, *Chem. Eur. J.* **2018,** *24*, 9820-9832
- A.M. Abudayyeh, O. Schott, H.L.C. Feltham, **G.S. Hanan**, **S. Brooker**, *Inorg. Chem. Frontiers*, **2021**, 1015
- **S. Rodríguez-Jiménez**, **M.S. Bennington**, A. Akbarinejad, E.J. Tay, E. Chan, Z. Wan, A.M. Abudayyeh, P. Baek, H.L.C. Feltham, D. Barker, K. C. Gordon, **J. Travas-Sejdic**, **S. Brooker**, *ACS Appl. Mater. Interfaces,* **2021**, 1301-1313
- **V. Singh**, A.M. Abudayyeh, M. G. Robb, S. Brooker, *Dalton Trans.*, **2022**, 4166–4172

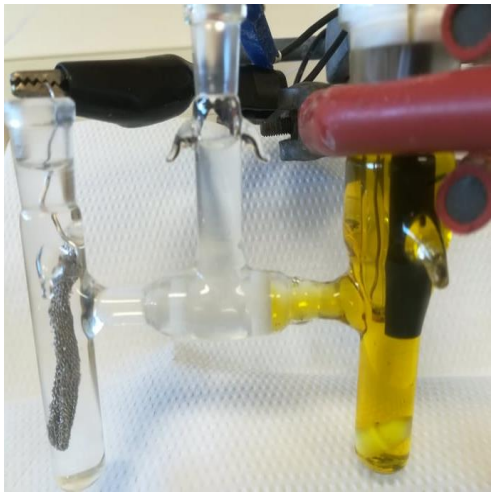
Photo/electro-catalytic carbon dioxide reduction: initial testing of our complexes very promising!



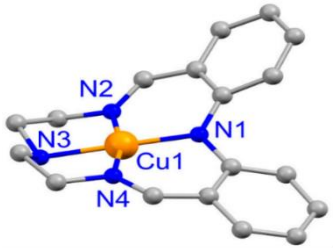
J. Hammonet, M.S. Bennington, K. DeMonte, V. Singh, F. Akogun, A. Abudayyeh, O. Schott, **G.S. Hanan**, **A. Marshall**, S. Brooker

Have in house **homogeneous HER electrocatalysis** capability

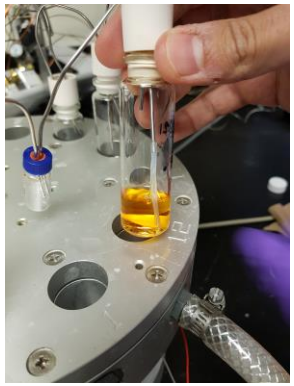
Now optimising **homogeneous CO2RR electrocatalysis** capability (with Prof Aaron Marshall, Canty)

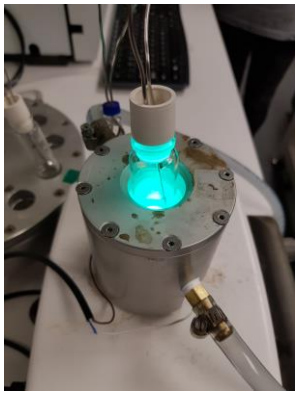


New PhD students (2022-):
Varinder Singh (Otago)
Kieran DeMonte (MacD)



Collaborating with Prof Garry Hanan (Montreal) using his **homogeneous photocatalytic HER&CO2RR** systems:





CATALYST FUND

Université de Montréal

Now developing **homogeneous HER photocatalysis** capability in NZ (with Prof Aaron Marshall, Canty)

RA (**0.25 FTE**) **Michael Bennington** working in collaboration with **Prof Aaron Marshall** funded by AETP SSIF (2021-2027); prev. MI

Ross W. Hogue, O. Schott, **G.S. Hanan**, **S. Brooker**, *Chem. Eur. J.* **2018,** *24*, 9820-9832
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Varinder Singh, Abdullah M. Abudayyeh, M. G. Robb, S. Brooker, *Dalton Trans.*, *51*, 4166–4172, **2022**.

CATALYST FUND

MacDiarmid Institute

“Safe, low cost, hydrogen storage materials from NZ resources”

Professor Sally Brooker (Chem, Otago) and Dr Paul Jerabek (Institute for Hydrogen Technologies, Helmholtz Zentrum hereon) with Aimee Kaio (Ngāi Tahu, Awarua), Dr Linda Wright (NZ H2 Council), A/Prof Nigel Lucas (Otago), Dr Anna Garden (Otago), A/Prof Michael Jack (Otago), A/Prof Jonathan Leaver (Unitec), Dr Chris Bumby (RRI, Vic), A/Prof Alex Yip (Canterbury) and Prof Peng Cao (Auckland) in NZ; and the German team from HZH includes Drs Klaus Taube, Claudio Pistidda, Lars Baetche, Julian Puszkiel, Thomas Klassen; plus **5 PhD and 3 Masters candidates**.

- develop **safe, large scale, long term H2 storage materials using TiFe metal alloys from NZ resources**, with outstanding hydrogen uptake characteristics and cycling durability
- use **state-of-the-art theoretical models**, to build understanding of mechanisms governing H2 absorption and desorption by these materials, enabling ‘smart design’ of new TiFe materials with unprecedented hydrogen storage performance, produced from low-cost raw materials
- **leverage world-leading expertise and experience from NZ and Germany**, across chemistry, materials, and engineering from Otago, Victoria, Auckland, Canterbury and Unitec, and the internationally-renowned Institute of Hydrogen Technology at Helmholtz-Zentrum Hereon (HZH)
- target this **essential enabling technology for NZ’s transition to a H2 economy**, addressing through **technoeconomic analysis** the issues of commercial viability and scalability of large-scale, high-capacity, long-lifetime, low-cost H2 storage technology, for enabling storage, transport and buffered distribution of energy generated from renewable sources, such as water and wind, with zero-carbon emissions, and thereby move NZ closer to a state of energy resilience and independence