Addressing climate change in Aotearoa New Zealand

Carr R[1]

[1]*Climate Change Commission*

The transformation of energy stored in fossil fuels to useful forms of energy in the right place at the right time powered the industrial revolution. Ten thousand hours of labour in a barrel of oil rendered slavery and child labour unnecessary, eliminated human dependence on natural light and overcame the tyranny of distance in constraining trade, human mobility and the sharing of knowledge. But the combustion of fossil fuels in the open air had externalities which have been known since the 1850s.

We have only a couple of decades in which we must transform how we generate useful energy sustainability. We have the technology but will we act in time? What are the barriers to timely, effective action?

Energy Transition in Taranaki: A 'Just Transition' for whom?

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As part of Central Government's efforts to support a transition to a low emissions economy, the Just Transitions Unit was created to help, in partnership with iwi, communities and regions, manage the impacts and maximise the opportunities of transition in a way that is fair, manageable and equitable.

With the ban of new offshore oil and gas exploration in 2018, the Taranaki region became the focus for this work due to the significant impacts the ban would have to the energy sector there. As a result, we have the juxtaposition of regional development and sectoral (and largely economic) transitions underway in Taranaki. Based on interviews with key stakeholders in the region and in Central Government during the development of the Taranaki 2050 roadmap and the planning for the Just Transition Summit in 2019, this research explored the implications of different definitions of justice and of transition in Taranaki.

Tensions across diverse perspectives highlight the challenges and opportunities of creating stronger linkages between sectoral and place-based approaches to transition and reinforce the need to think about just transitions not just in terms of outcomes (e.g. low emission economy) but also in terms of the processes involved in acknowledging and addressing past injustices.

Energy trends in Dunedin - are we heading in the right direction? Results of the Dunedin Energy Study 2018-19

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How much energy does Dunedin city consume a year? What fuels are most widely used? Are our energy-related carbon emissions increasing or decreasing?

At the Centre for Sustainability we have been reporting topics such as these for the past 5 years as part of the annual Dunedin Energy Study, funded by Dunedin City Council. The Energy Study has become an important information source for the Council to track progress with its Energy Plan, and more recently to help evaluate progress with Council's commitment net zero carbon by 2030. Dunedin city's boundaries extend inland to Hyde, south to Waihola and north to Waikouaiti, so the study area includes farms, forests and small settlements as well as the urban area of Dunedin itself.

The study, unique in New Zealand, relies heavily on the generosity of a large number of Dunedin firms and organisations who provide their data on energy supplies and energy uses.

We will present on the latest findings on energy flows into the city (e.g. petrol, diesel, LGP, coal, wood pellets, electricity) and produced from within the city's boundaries (e.g. firewood, wood chips, some electricity). We will cover the main uses of different fuel types, and the associated greenhouse gas emissions. In this year's report, for the first time, we have a sufficiently robust data series to be able to look at some trends over the past few years. We will report on the good news and the bad, and finish by suggesting key areas for action.

To what extent has COVID-19 impacted hard-to-reach energy users?

Rotmann S[1]

[1]*User-Centred Energy Systems Technology Collaboration Programme, International Energy Agency*

Energy users who rarely participate in efficiency and conservation programmes despite ongoing outreach, are often referred to as 'Hard-to-Reach' (HTR). These individuals or organisations can include, e.g., *low income* or otherwise *vulnerable* households; and *small businesses*. More effectively engaging HTR audiences is key to ensuring everyone benefits equitably from energy efficiency policies and programmes. This is even more the case in light of the COVID-19 pandemic, and the ongoing implications for energy use and affordability for the most (and newly) vulnerable members of our society.

This research is part of a 3-year project for the *User-Centred Energy Systems Technology Collaboration Programme* (Users TCP) by the International Energy Agency (IEA). The purpose of this initiative is to characterise the diverse energy user segments commonly referred to as HTR and to uncover the barriers and behavioural opportunities to more effectively engage these audiences. The project focuses on HTR audiences from the residential and non-residential sectors.

We have undertaken a broad stakeholder analysis (Ashby et al., 2020) and in-depth literature review (Rotmann et al., forthcoming) characterising HTR audiences (segmented into vulnerable & high-income households; renters & landlords; commercial sector; and SMEs), target energy-saving behaviours, and barriers. As part of this review, we looked at the impacts of COVID-19 on these audiences, including their added vulnerabilities, and massively increased size estimates. In addition, we collected survey, interview and focus group data during the COVID-19 pandemic in the US, UK, New Zealand and Sweden. This talk will provide some summary highlights of these findings.

Techno-economic Analysis of Options to Achieve 100% Renewable Electricity for Samoa

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To reduce greenhouse gas emissions and reliance of fossil fuels Samoa has developed a target of achieving 100% renewable electricity by 2025. Currently 60% of Samoa's electricity comes from diesel generators and the details of how this target will be achieved are not clear. This research aims to provide a better understanding of how to achieve this target by analysing possible future renewable electricity supply scenarios.

This analysis modifies historical data to simulate detailed time series of electricity demand and renewable electricity supply for a range of possible future scenarios.

Due to excellent solar resources, our results show that it is technically feasible to achieve close to 100% renewable electricity supply in Samoa with a combination of solar photovoltaics, hydro and electricity storage. The most promising scenarios to achieve this have shares of solar, hydro and stored solar electricity supply in the range of 28 - 37%, 25 - 40%, and 17 - 30%, respectively. Storage size range of 110MWh to 180MWh was found to be critical to achieving these results. Scenarios with very high percentages of renewables (> 90%) resulted in prohibitively high costs. However, by optimizing storage size, it is possible to find scenarios that achieve ~90% renewable supply *and* appear economically viable. For example, these scenarios give a Net Present Value > 0, and have indicative Levelized Costs of Energy that are below the current cost to produce electricity in Samoa.

The Role of Fundamentals and Policy in New Zealand's Carbon Prices

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New Zealand's Ministry for the Environment (MfE) explicitly recognizes that the New Zealand Units (NZUs) price is set by a flexible unlimited supply of units, as well as demand for units.

We explore NZU pricing dynamics driven by the interaction between allowances supply and demand. The empirical results highlight that, firstly, there are two policy associated structural breakpoints in NZU returns over the period of 2010- 2019. The first was in 2013 following a large ban on international units with low environmental integrity and the second was in 2016 following the announcement of a gradual phasing-out of one-for-two 'transitional' measure. Secondly, increased carbon activities from the manufacturing and transportation sectors tend to increase NZU prices, while activities from the stationary energy sector put downward pressure on NZU prices. This may be explained by the large stockpile (bank) of unit held by stationary energy sector. Lastly and as expected, the results show that banking and net import negatively affect NZU returns, however, carbon removal entitlements surprisingly positively affect NZU returns.

Quantifying Firm-Level Barriers to More Effective Private Sector Involvement in the Transition to Low Carbon Energy System

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Despite the progressive investment in low carbon power generation, there remain a sizeable shortfall of investment flows into this sector due to investment barriers that exist within countries. Our study seeks to measure the perceived barriers and enablers that guide company's decision-making process to undertake low carbon investment (LCI).

We adopt the Multilevel Perspective approach to group the elicited measures of perceived LCI barriers into: (i) firm-, (ii) market-, and (iii) policy-level factors. Investment enablers are classified into desired (i) policy changes, (ii) policy tools, and (iii) additional financial incentives.

First, we analyse how decision makers in different types of organization and geographic regions perceive the relative importance of these measures using Ordinary Least Squares (OLS) and augmented by Fixed Effects (FE). Second, we conducted semi-structured interviews to gain more information than that provided by the quantitative data in order to empirically investigate how these measures are being played out in low carbon projects (i.e., geothermal investment in Indonesia and New Zealand).

Our analysis suggests that perceived barriers are more uniform at the firm-level and are more divergent at the broader level (e.g., market- and policy-level). ASEAN respondents have generally positive coefficients on the barriers variables than the OECD respondents do, suggesting that LCI is perceived to be more challenging for ASEAN respondents.

The overarching goal of our analysis is to identify region- and organization-specific barriers and enablers that, if improved in favour of further incentivizing LCI, would translate into substantial increases of capital flow into this sector.

The World Energy Outlook 2020

<u>McGlade C[1]</u>

[1]*International Energy Agency, Paris*

The World Energy Outlook 2020, the International Energy Agency's flagship publication, provides a comprehensive view of how the global energy system could develop in the coming decades.

This year's exceptional circumstances require an exceptional approach. The usual long-term modelling horizons are kept but the focus for this new Outlook is firmly on the next ten years, exploring in detail the impacts of the Covid-19 pandemic on the energy sector and the near-term actions that could accelerate clean energy transitions.

The analysis targets the key uncertainties facing the energy sector in relation to the duration of the pandemic and its implications, while mapping out the choices that would pave the way towards a sustainable recovery.

The strategic insights from the *WEO-2020* are based on detailed modelling of different potential pathways out of the crisis, covering all regions, fuels and technologies and using the latest data on energy markets, policies and costs.

The impact of COVID-19 on EV driving behaviour: findings from Vector's Auckland EV trial

Parker R[1]

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Understanding electric vehicle (EV) charging behaviour is essential for seamlessly integrating a high uptake of EVs into an electricity network. While rapid uptake of EVs has the potential to cause negative impacts on an electricity network, these may be mitigated through various forms of 'smart charging'. Smart charging involves temporally shifting EV demand to periods where other network demand is low, ideally in a manner that doesn't impact the EV owner.

As part of their New Energy Futures initiative Vector Ltd has installed ~130 smart EV chargers in residential households around Auckland. These smart chargers log charging behaviour and may be remotely scheduled to better understand impacts to both the customer and the electricity network that smart charging may bring about.

This presentation introduces Vector Ltd's EV smart charging capabilities, as well as providing a high-level overview of Auckland EV charging behaviour pre-COVID-19. It then demonstrates the impacts of COVID-19 on Auckland EV charging behaviour. Changes in EV electricity demand for each lockdown level, as well as the period between New Zealand's lockdowns is quantified.

Developing Offshore Wind in New Zealand: technical, socio-economic and environmental issues in relation to a post-pandemic future

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In order to transition to a 100% renewable energy system New Zealand will need to double present electricity production to about 80 TWh per year by 2050, and simultaneously embark on a programme of large-scale electrification of stationary energy and transport. Offshore wind has the potential to contribute a large proportion of this demand, while also representing a high-profile infrastructure investment opportunity for New Zealand, creating highly skilled jobs and providing the supply for large scale green hydrogen production in which there is presently considerable interest at governmental, local and industry levels.

In this presentation we will first outline the technical potential, advantages and engineering issues for a large offshore wind farm considering both fixed and floating wind turbines in the South Taranaki Basin. Then key socio-economic topics including a roadmap to consenting, local employment during design and construction, long-term operation and maintenance and the transition from existing oil and gas activity will be discussed, with consideration given to the financial resilience of large renewable energy infrastructure projects in times of economic downturn. Finally, the environmental impacts of offshore wind farms including visual impact, effects on surfing and issues for marine life are explored. We will also present an overview of the work of the NZ Offshore Wind Working Group and discuss current offshore wind developments in Australia.

How do household electricity consumption patterns change after PV adoption?

Dortans C[1]

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With solar photovoltaic (PV) now being competitive with conventional electricity generation, the penetration of PV nationally and internationally is expected to rise. Generation capacity is likely to take on a distributed pattern with households actively contributing to the vital balance between electricity supply and demand.

However, electricity consumption patterns in households following PV adoption, and the resulting timing and amount of electricity flows into and out of the local grid, will significantly affect the extent to which electricity from PV can facilitate a fully renewable grid. Furthermore, as the cost associated with battery storage is decreasing, electricity flows will increasingly be mediated by household battery systems. With smart energy systems, these can store and release surplus generation into the grid. This creates further opportunities for distributed generation to overcome the challenges associated with volatile renewable generation, but also brings new and unclear patterns of use and supply to the local grid.

This field is under-studied internationally and in New Zealand. Our review of international literature portrays an ambiguous picture on whether the adoption of PV leads to an increase or decrease of electricity consumption, and/or a shift in the timing of household activities. The majority of studies are based on self-reported data, while studies based on monitored data are typically small in number.

We discuss the issues and opportunities of this emerging transition, present the results of the review of the literature, and outline the next steps in this PhD project.

New Zealanders' attitudes about collective action against climate change in the wake of COVID-19

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[1]*Centre for Science Communication, University of Otago*

Early in the COVID-19 pandemic, commentators theorised that the collective response would increase support for collective climate action (CCA). While it has been previously shown that collective efficacy (beliefs about the ability of one's group to perform collective action) may improve following other instances of successful collective action, we are not aware of an empirical test of this with regards to COVID-19 and climate change.

An online survey of New Zealanders (N=796) examined relationships between attitudes towards CCA and collective action against COVID-19. We also examined the effect of persuasive and non-persuasive interventions about collective action against COVID-19. Respondents were randomly assigned to either 1) read a persuasive essay, or 2) complete a series of attitudinal questions on the same topic as the essay, or 3) no intervention.

Preliminary analysis indicates that collective action has not been politicised in New Zealand to the same extent as CCA, with considerable differences on the basis of political affiliation. Left-of-centre voters showed lower collective efficacy than right-of-centre voters. In contrast CCA was more widely supported by left-of-centre voters and opposed by right-of-centre voters. Climate change beliefs and attitudes similarly fell along political lines. One of the interventions relating to COVID-19 had a small negative effect on attitudes about collective efficacy when viewed across the whole sample.

These results suggest that COVID-19 may not have had the positive impact on support for CCA that many have hoped for. Climate communicators can apply these results when crafting messages for audiences with varying political identities.

A large energy exporter in a net-zero global energy system: Australia

Jotzo F[1]

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How will a fossil fuel heavy economy like Australia fare in a transition to a net-zero emissions energy system?

This talk will lay out what a close-to-zero-emissions domestic energy system is likely to) look like, and what Australia's opportunities could be in establishing renewable energy based export industries. The paper will synthesize the broad lines of technological options and scenarios for the shift to zero emissions energy, and the prerequisites for that transition to happen. It will canvas economic, societal and political ramifications of the transition, including financing and taxation, and the inevitable shifts in economic activity between regions and corporate interests.

Geothermal energy from extinct volcanoes: the Dunedin experiment

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Significant amounts of carbon-based fuels are burned in New Zealand and globally to generate heat for buildings and manufacturing. Here we ask: can residual heat from extinct volcanoes be harnessed as a geothermal energy resource thereby reducing carbon-based fuel consumption and consequent greenhouse gas emissions?

We aim to address this question by drilling two 500-metre deep geothermal exploration wells into the 11-million year old Dunedin Volcano to monitor the residual heat (heat flow) from the now solidified magma chamber that lies beneath. These measurements will be used to generate a 4-D spatial-temporal geological model of the volcano, determine the extent of the present geothermal resource, and estimate the potential economic and environmental benefits of using this resource for heating.

Successful utilization of this geothermal resource, if of sufficient size, will have long-term economic benefits both locally and nationally. In Dunedin, the principal users of heat are the Dunedin Hospital, University of Otago and the CBD. Reduction in fuel costs will translate into direct economic benefit for them as well as indirect savings for central government through funding of health services and tertiary education.

The expertise developed from this project will be of interest nationally and internationally. Extinct volcanoes with residual heat exist elsewhere in New Zealand (Northland, Waikato) and around the world (central France, eastern Australia, Pacific islands) and may be employed in a similar manner. As far as we are aware, these have not been previously considered as viable geothermal resources. We seek to change this.

CO2 as a Refrigerant: An Environmentally Friendly and Cost-Effective Solution for NZ Businesses

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[1]*CoolLogic*

[2]*Department of Physics, University of Otago*

Carbon dioxide, I hear you say? Isn't that a greenhouse gas? A baddy for the climate? Yes. Every time we burn coal, oil or gas, carbon dioxide is released, warming the atmosphere but when used as a refrigerant CO_2 becomes the good guy. Prior to the Montreal Protocol, refrigerants, such as trichlorofluoromethane, had high Ozone Depleting Potentials (ODPs). The refrigerants replacing these ozone depleting substances, such as chlorodifluoromethane, turn out to have high Global Warming Potentials (GWPs). We may replace these potent greenhouse gasses with more environmentally benign alternatives. One option is CO_2.

CoolLogic, a refrigeration engineering company, and Southern Clams, a Dunedin based seafood fishery, have collaborated to build a modern, water-cooled, two-stage transcritical CO_2 refrigeration system with additional heat-reclaim technology and is one of New Zealand's first. Running since September 2019, the newly developed system uses only 60kg of CO_2, costing totally \$600, compared to the cost of R404a (a blend of tri-, tetra-, and penta-fluoroethane) which would reach over \$30,000 for an equivalent system. The efficiency gain of the new plant exceeds 20% compared with the previous system and the heat reclaim provides over 100 kWh of domestic hot water per week.

The cost of replacing Southern Clams' conventional plant with a CO_2 refrigeration system is offset by the efficiency gains, low refrigerant cost and the ability to produce plentiful, quality heat.
A preliminary theoretical analysis of the plant was conducted through the University of Otago's Energy Management program in collaboration with Southern Clams and CoolLogic.

Copper catalysts for hydrogen production

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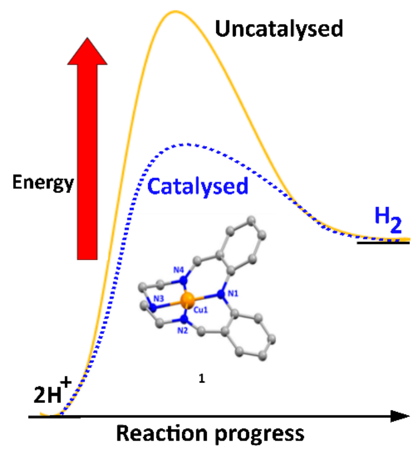
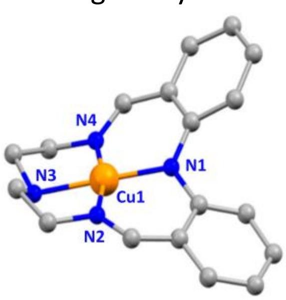
As part of efforts to tackle global warming and climate change, hydrogen, a zero-carbon fuel, is receiving great attention. When burned, hydrogen produces only water and energy.

$$2H_2 + O_2 \rightleftharpoons 2H_2O + \textbf{Energy}$$

Most hydrogen production involves the use of fossil fuels and elevated temperature, producing “brown hydrogen”, and small amount involves “electrolysers”, which is “green hydrogen” if the electricity used is renewable. To reduce the energy required to drive green H_2 production to make it more cost competitive, effective catalysts are needed.



Three copper complexes **1**-**3,** have been prepared and studied as hydrogen production catalysts, with **1** a promising catalyst.



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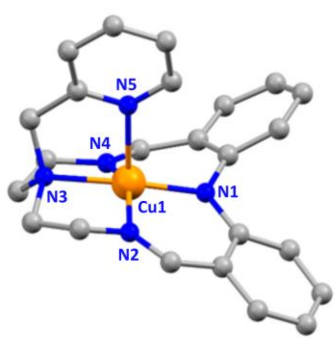

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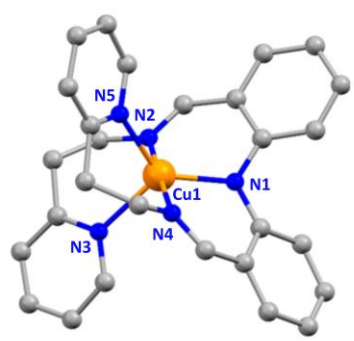

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Net energy analysis of New Zealand energy sources: Will we have enough energy in the future?

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Net Energy Analysis is a simple methodology to determine the net or surplus energy available to do work in society. It is calculated by subtracting from the total energy produced, the amount of energy required to produce that energy, from any particular energy resource or technology. Net energy is often expressed as a ratio of Energy Return on (Energy) Invested, or EROI (EROEI).

Determining net or surplus energy is important because that is the amount that determines how much work can be accomplished, other than producing more energy. Most energy discussions focus on total energy produced rather than net energy. This approach made sense when the difference between the two was negligible, as was the case in the early days of fossil fuels. Early oil had an EROI of over 100:1, a significant increase over wood.

Today, fossil fuel EROI is less than 15:1 and declining. Furthermore, all renewable energy sources (other than hydroelectric) have lower EROI ratios than fossil fuels. When the energy inputs required for dealing with the intermittencies of wind and solar are considered, the EROI for a mostly renewable energy system is shown to be less than 5:1.

While NZ has unique hydroelectric resources there have been very few studies of net energy returns on a mostly renewable energy system in NZ. This is critical information for determining what our energy future will be. Decision makers need to integrate net energy analysis into their investment decisions.

Using Domestic Hot Water Cylinders as an Energy Storage System to increase Variable Renewable Electricity Supply in Microgrids

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Due to the need for energy security, increasing demand for renewable electricity and mitigation of the effects of natural disasters, microgrids are being deployed for a decarbonized and decentralized energy grid. The variability of both renewable energy sources and electricity demand creates a significant supply-demand mismatch in microgrids. This is normally dealt with dispatchable fossil sources which increase emissions. In this project, we explore the opportunity for residential hot water cylinders to be used as an energy storage system to address this supply-demand mismatch.

In this project, we aim to develop a simulation of the hot water usage of a number of residential households. This simulation is based on novel approach that determines hot water usage based on reverse engineering measured electricity data from the households. This hot water usage simulation can then be used to model a range of scenarios where the hot water cylinder elements are controlled to balance renewable supply without compromising hot water service.

We will present an evaluation of the accuracy of the hot water usage simulation and preliminary results that quantify the ability of hot water cylinders to balance variable solar photovoltaic supply in a 20 house microgrid.

Assessing of the real-world performance of low-e window films in commercial buildings using an infrared camera

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In order to meet ambitious government and organizational greenhouse gas emission reduction targets, new measures for improving the energy efficiency of buildings are needed.

One promising low-cost approach to improving building energy performance is to retrofit existing windows with low-emissivity (low-e) window films. These films reflect the infrared (heat) portion of the electromagnetic spectrum back into the building but have little impact on the visible part of the spectrum. While these films seem promising based on laboratory measurements, there has been little assessment of their performance in real-world situations. Assessing the thermal insulating performance of building components has historically required complex time-consuming measurements with expensive specialist equipment. Recently there has been a growing interest in thermographic techniques using cameras that can detect the infrared spectrum. This could provide a quick and method of evaluating the thermal performance of window films.

This poster will present preliminary results of an Energy Living labs collaborative project funded by the Sustainability Office that uses and infrared camera to evaluate the in-situ performance of low-e films retrofitted to a number of University of Otago buildings.

If shown to be effective, widespread use of these films across a larger proportion of the University buildings could be a low cost method of reducing heating energy demand at the University and reducing associated greenhouse gas emissions. The results could also assist with decision-making about window films across all of New Zealand’s commercial buildings.

Dynamics of water splitting kinetics by cyanobacteria; potential source of fuel

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Plants and cyanobacteria are natural rescuers to assimilate CO_2 and H_2O (greenhouse gases) and they produce O_2 and carbohydrates in a process called photosynthesis, a term coined by Charles Barnes in 1893.

A profusely available form of renewable energy is solar energy and the chlorophyll-containing organisms have the ability to convert that energy into other forms of energy. These organisms make food for their own existence, split water and release O_2 in the environment.

Zero-carbon emission is not only related to the reduced emission of greenhouse gases in the environment but also requires looking for alternative cost effective, environment friendly, and sustainable sources of fuel for industry. O_2 and H^+ are the byproducts of photosynthesis. O_2 is the fuel for our environment whereas hydrogen is a fuel for industry. Most of the hydrogen consumed by industry comes from the oxidation of the non-renewable fossil fuel.

The problems associated with the use of these fossil fuels is production of greenhouse gases and obviously their non-renewable nature. Nature has taught us to split water molecules in an environment friendly, sustainable and economical fashion in the form of photosynthesis.

Cyanobacteria have a number of advantages to study photosynthesis as a model system because of the availability of the complete genetic makeup in the literature. Cloning, inactivation of specific genes or introducing point mutations in the genetic makeup of cyanobacteria is well established and cyanobacteria compare favorably with plants because of their compact genome and short generation time. Targeted changes in amino acid residues around the photosynthetic oxygen-evolving complex (OEC) to increase the electrophilic character of the OEC is the area of study of my research.

The goal of this research is to investigate changes that may increase the rate of O_2 evolution. The OEC is formed by a specific catalytic Mn-containing cluster and the start of the photosynthetic electron transport chain. The potential outcomes of this study can be exploited for the biological production of hydrogen for fuels or as increased biomass that can be harnessed for the production of biofuels.

Just like Covid-19, the global problem of greenhouse gas emission is not specific to any country or continent. In particular, finding alternative ways to generate fuel and to reduce the emission of greenhouse gases will have a substantial impact on the areas located in proximity to the oceans by reducing the impact of rising water levels that result in erosion and flooding.

Development of Coating-Free Super Water-Repellent Aluminum Micro-Gradient Surfaces for Enhanced Water Management

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Superhydrophobic (SHPB) surfaces demonstrate extreme water-repellence, promoting dropwise over filmwise condensation, increasing liquid mobility and reducing thermal resistance. By introducing a gradient in surface tension, additional in-plane forces can promote greater water shedding capability, potentially allowing surfaces to remain ice- and frost-free under extreme weather conditions. Such surfaces could potentially reduce ice-formation on wind turbine blades and frost-formation on refrigeration heat exchanger surfaces, improving energy efficiency. While coated surfaces have shown anti-ice/frost properties, they are prone to wear.

The lotus leaf exhibits superhydrophobicity, arising from its hierarchical surface consisting of random microscale bumps with superimposed nanoscale hairs. Furthermore, nature has evolved systems that passively transport water droplets. For example, the hydrophilic spider-silk of some spider's webs can promote passive motion of sub-millilitre water drop motion through spindle-knot/joint couplings which setup gradients in surface tension and Laplace pressure. We look to combine and replicate the super-water repellence of the Lotus leaf and the surface tension gradient driven motion of water droplets on spider silk in an all metal (coating-less) system.

We present a survey of our microstructures and their resultant wetting properties on fixed-pitch and variable-pitch microstructures. In addition, we report progress on the development of all metal hierarchical superhydrophobic gradient surfaces. Such metal surfaces would have the advantage of not requiring coatings, which wear-out.

3D-Printed Heat Exchangers with Improved Drainage Properties via Surface Micropatterning

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[1]Department of Physics, University of Otago

Nature has evolved a mastery of water droplet management over millennia. For example, the surfaces of rice leaves and butterfly wings possess microstructured lines that allow preferential motion of water droplets along the microlines and greater flow resistance perpendicular to lines, leading to excellent water-shedding properties. Incorporating such properties into condensing heat exchanger technology could provide benefits in terms of energy efficiency and as a result, reduced GHG emissions.

Heating, Ventilation, Air-Conditioning and Refrigeration (HVAC&R), represents more than 17% of global electricity consumption. An integral component of most HVAC&R systems is the condensing heat exchanger. Research has shown that a condensing aluminium heat exchanger with micropatterned fins can reduce air-side pressure drop by 36%. This micropatterning has not been trialled for performance improvements in polymer heat exchangers which have benefits over metal heat exchangers such as being light-weight and having reduced cost, but with the disadvantage of reduced thermal properties compared with their metal counterpart.

It the present work, using fused filament fabrication (a 3D-printing technique), we have prepared microstructured heat exchanger surfaces and ducting in order to assess whether such micropatterns can improve a polymer heat exchanger's drainage properties. Here we investigate a 3D printed heat exchanger surface and 3D-printed plate-type condensing heat exchanger ducting with various microstructure surface alignment configurations to assess whether drainage properties can be improved compared with smooth control surfaces (metal and polymer).

Results show that microstructure alignment with gravity demonstrates optimal water-shedding performance compared with other orientations as well as against smooth control surfaces.

Characterising Anti-ice and Anti-frost Properties of Micropatterned Aluminium

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Ice and frost formation on surfaces creates efficiency problems for many different energy generation and conversion applications, including solar panels, refrigeration and wind turbines. For example, ice on wind turbine blades reduces aerodynamic efficiency and power generated. Frost formation on heat exchanger surfaces (used in Heating, Ventilation, Air Conditioning and Refrigeration [HVAC&R]) increases thermal resistance, which reduces efficiency and increases energy use. To delay ice formation, hydrophobic (water repellent) coatings may be used however these coatings tend to wear quickly and are therefore a very short term solution where periodic reapplication is impractical.

Using periodic, aluminium microstructures, designed for hydrophobicity, we aim to characterise two icephobic metrics for these surfaces: 1) ice adhesion strength and 2) frost formation time. Here we present results for ice adhesion strength measurements on smooth control and micropatterned aluminium surfaces. These measurements were achieved using the force probe method. In addition, preliminary frosting delay times have been measured on these surfaces in a bespoke wind tunnel which has been developed as part of this work.

Results show that microgradient surfaces can potentially reduce ice adhesion strength as well as extend frost formation time, showing them as a promising candidate structure over fixed pitch micropatterned aluminium surfaces.

Climate Justice or Climate Ghettos: the complex social challenge in adaptive housing and our new energy future

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Our stable climate is no longer. We have entered uncharted territory, and we are struggling to know how to adapt. The Climate Safe House project was an essential socio-technical experiment to address the housing crisis, the climate crisis and the clean-tech transition initiated in 2016 and delivered in 2020. As a flax-roots solution to deliver climate justice we hoped to deliver a blueprint for combined mitigation and adaptation action.

We set out to design and build a new type of housing that was affordable, transportable, modular, energy efficient and with a low environmental footprint, all connected to the local smart grid. All of those objectives were achieved: sensors illustrate the high thermal performance and the life cycle analysis shows a low emission build, while electricity is shared within the community.

We are continuing to innovate, we are learning more about the vulnerability of exposed communities and the cascading impacts of various shocks and stressors.

The house is now being sold and relocated. It's a successful demonstration of its objectives, including 'transportability', but also highlights the challenging reality of disruption to people's lives.

In this paper we examine what might be needed to avoid negative mental health outcomes in our changing climate, and what is now possible with existing technologies. We also look at what support structures could be enhanced to reduce community vulnerability. This is the story of the Climate Safe House and the complexity of flax-roots adaptation.

Building software systems to support interactively exploring energy data

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Research into use of electricity can require handling large datasets of high frequency meter data that may come from multiple sources. This presents a number of challenges which include: (a) how to effectively interact with and explore the data to discover patterns, (b) how to scale up the analysis from subsets to the entire dataset, and (c) how to easily make the software pipeline that produces the analytical results reproducible, itself.

In this talk we present our work on developing a scalable platform for data ingestion, processing, storage and visualisation of multiple datasets. Using a dataset of the power consumption of a number of buildings at the University of Otago, and measurements from the online weather sensors hosted by the Department of Physics, we have developed tools for processing raw data into a time-series database that facilitates analyses being performed across multiple data sources. To aid exploration and analysis of the data, a visualisation component is included that provides a way of interacting with the data even at large scale. The platform is extensible, allowing custom plugins to be used for visualisation, analysis, and reporting. The design of the platform supports operating at large scale, while also being able to be packaged up along with sample data that can be run on researchers' own computers to aid in software reproducibility. Our platform is a step toward reducing some of the challenges that face researchers examining and optimising energy use.

Quantifying the potential of ultra-efficient houses to reduce seasonal electricity demand and enable greater renewable supply

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Achieving high percentages of renewable electricity supply is made difficult by the nondispatchable and variable nature of many renewable sources which have a temporal mismatch with demand. Short term mismatches can be met by known technologies, such as batteries and demand response, however longer-term or seasonal mismatches such as between plentiful solar supplies and winter demand is much harder to solve. An extreme example of this is the well-known New Zealand "dry-year problem" which occurs in years when hydro resources are insufficient to meet winter peak electricity demand. Currently this inter-seasonal energy resource deficit is met through the use of non-renewable generation in autumn and winter and represents a significant barrier to transitioning to ~100% renewable electricity. Most solutions to this problem focus on capital intensive supply side or inter-seasonal storage options.

In this paper we consider a possible demand side solution. Currently most of the winter demand peak is caused by residential heating, which could be significantly reduced through widespread implementation of ultra-efficient low energy input housing. This paper analyses long-term scenarios where all residential new builds and retrofits achieve healthy temperatures and meet progressively higher energy efficiency standards. We then quantify the potential for these scenarios to reduce future demand for winter electrical heating. The results show that if all new builds and retrofits are completed to *currently* achievable best practice standards then total annual electricity demand could be permanently reduced to 1/3 of business as usual by 2050. They also show a significant lessening of the problematic difference between winter and summer demand to 1/4 (or 1.8 TWh/month) of business as usual. Such a reduction would make the decarbonisation of the New Zealand electricity and thus the overall energy system significantly easier to achieve. In combination with previous research, these results argue for the urgent implementation of cross-sector policies that mandate energy efficient residential buildings based on their wide ranging health, efficiency and energy affordability benefits *and* their role in helping achieve a decarbonised energy system.

Sustainability lenses: alluding to the precautionary principle through energy use and agriculture.

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Data describing sustainability is often presented using carbon dioxide equivalents with future visions focused on a zero-carbon future. This has merit, but achieving sustainability is seriously undermined by the very foundations of our industrial civilisation. This presentation takes a step back and looks at sustainability issues via energy because energy consumption and associated resource transformation is the basis of our economic system. Understanding energy and resource use is a prerequisite for comprehending why environmental degradation and climate change seem to be accelerating, and further unearths the mammoth scale of actually achieving some semblance of sustainability.

As an agricultural scientist my interests lie within sustainable food production. I will attempt to illustrate the 'sustainability' of current and future food production through the lens of 'energy-return-on-investment' (EROI). Although economically efficient, current western food production systems, ‘seed-to-table’ are energy negative, while new innovations aimed at reducing environmental effects and improving food ‘safety’ are likely to exacerbate climate change due to hidden energy costs. Using EROI we can more rationally frame the impacts transformations in agriculture might have and make some predictions about the trajectory of our future with respect to our environment. To navigate an energy constrained future we need to use knowledge and technology wisely to restore our relationship with the environment rather than assuming we can disconnect without adverse impacts.

Re-imagining Energy Futures through School-University Community-Engaged Teaching and Learning Collaborations

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In Feb-Mar 2020, a mutually beneficial relationship was brokered between 4th year Energy Practice students of Otago University and a primary school teacher of Musselburgh School placed with He Kaupapa Hononga: Otago's Climate Change Research Network as a host on the Royal Society Te Apārangi Science Teaching Leadership Programme at the University of Otago.

Key learnings from this partnership were:

1. *Authentic community-engaged learning and teaching approaches can provide development of science communication capabilities alongside the practical skills needed to carry out an energy analysis as the first step in designing improved energy systems in schools.*
2. *Relationships initiated kanohi ki te kanohi (face-to-face) develop the trust necessary to continue a collaborative partnership remotely, throughout various levels of Covid-19 lockdown.*

This community-based reciprocal teaching and learning approach actively engaged all participants in determining a common goal towards a low energy future while meeting partners' individual needs, including the lecturer, postgraduates, school Principal, Board of Trustees, teachers and school children.

The Energy audit focussed on possible behaviour changes to quickly reduce energy use and in depth assessment of past energy use and recommended long-term changes to behaviour and infrastructure to maximize efficiency over time. The next phase is engaging staff, students and Board of Trustees in using the audit's scientific evidence to help make decisions on new energy use behaviours and priorities for infrastructure maintenance, in keeping with their Enviroschools Principles and Strategic Direction.