15th OERC Symposium 2021

The Challenge of Net Zero by 2050

ABSTRACTS

EECA TE TARI TIAKI PŪNGAO
ENERGY EFFICIENCY & CONSERVATION AUTHORITY

NERI
National Energy Research Institute

KEYNOTE SPEAKER

Insights for the low-carbon energy transition from the IEA's World Energy Outlook 2021

Dr Stéphanie Bouckaert,
Head of Demand Sectors Unit, Senior Energy Anyalyst @ IEA

A new energy economy is emerging around the world as solar, wind, electric vehicles and other low-carbon technologies flourish. But, the IEA's new *World Energy Outlook* makes it clear that this clean energy progress is still far too slow to put global emissions into sustained decline towards net zero. The new analysis delivers stark warnings about the direction in which today's policy settings are taking the world. But it also provides clear-headed analysis of how to move in a well-managed way towards a pathway that would have a good chance of limiting global warming to 1.5 °C and avoiding the worst effects of climate change.

The *WEO-2021* spells out clearly what is at stake: what the pledges to reduce emissions made by governments so far mean for the energy sector and the climate. And it sets out what needs to be done to move beyond these announced pledges towards a trajectory that would reach net zero emissions globally by mid-century – the **Net Zero Emissions by 2050 Scenario** from the landmark IEA report published in May, which is consistent with limiting global warming to 1.5 °C.

DAY ONE

National Energy Modelling – co-organised with NERI

NZ Energy Scenarios, TIMES-NZ

Dr Gareth Gretton, EECA

How we supply and use energy in the future will have a major impact on how successfully we respond to the challenge of climate change, and the TIMES-NZ 2.0 model seeks to provide more information and insight into the choices we face.

The TIMES-NZ 2.0 project is a collaboration between the Energy Efficiency and Conservation Authority (EECA), the BusinessNZ Energy Council (BEC) and the Paul Scherrer Institut (PSI) in Switzerland. It is an evolution of the BEC2060 project, developed by BEC as an exploration of possible energy futures based on contrasted scenarios.

The TIMES-NZ model is based on the IEA ETSAP Technology Collaboration Program modelling methodology. TIMES is an internationally recognised modelling approach used in over 60 countries. TIMES-NZ is an instance of the international modelling standard which has been adapted to cater for New Zealand's energy system needs across sectors.

This latest iteration – the 2.0 model – builds on the BEC2060 work by adding more detail and sophistication to sectors, subsectors, technologies, and end uses. Assumptions and data inputs draw on EECA's Energy End Use Database (EEUD) with additional input from project partners and many additional contributors.

The Kea and Tūī scenarios from the BEC2060 work have been retained and extended. These two plausible and coherent scenarios differ in the underlying assumptions of GDP growth, carbon price, technology cost curves and discount rates, and provide an indication of how our energy system could develop over the next 40 years.

Energy Systems Modelling for a Changing Climate

Ian Mason, University of Canterbury

In this presentation the state of the art in energy systems modelling is briefly reviewed, and current trends and challenges identified. Some issues relating to choosing a model are outlined and two models compared on the basis of their capabilities and applications. A new modelling paradigm is then proposed to address issues related to a changing climate, and key additions plus further model development are discussed.

Price Formation and Investment in a 100% Renewable Electricity Market

Greg Sise, Managing Director, Energy Link;
Honorary Research Fellow, Accounting & Finance Department, University of Otago
Affiliations: Energy Link; Climate & Energy Finance Group, University of Otago

The literature around very high penetration of variable renewable energy (VRE) in the electricity sector is focused on technical feasibility and on the cost of the technology. But assuming 100% VRE is technically feasible, achieving a market with 100% VRE requires investment in sufficient plant to meet demand. New Zealand has an energy-only market in which expectations of future spot prices are a key driver of investment decisions by firms. This research looks at the question of how spot prices will be formed with 100% VRE under various physical configurations and government interventions, and the conditions that need to be met to ensure that the investment required to achieve 100% will be forthcoming.

100% renewable 2030 or 2040? – the implications

Dr Jen Purdie
Centre for Sustainability – University of Otago

The government has vowed to push for a 100% renewable electricity system in New Zealand by 2030, despite the Interim Climate Change Committee calling for a "high proportion" of renewable energy instead and suggesting the accelerated electrification of transport and industry is a better goal. Keeping a very small proportion of gas in the electricity mix enables a much more flexible electricity system, the ability to cover winter evening peaks in dry years, much less volatile pricing, and lower electricity prices overall. With the ICCC and the Climate Change Commission both calling for significant electrification of transport and industrial heat, a possible doubling of electricity demand by 2050 has been postulated (Transpower 2020 Whakamana I Te Mauri Hiko report). A secure, robust electricity system that can handle high demand peaks and dry year risk is vitally important to enable this decarbonisation.

This paper uses an all of New Zealand electricity system model (LPCon) to imagine two futures: one where the electricity system is 100% renewable by 2030, and the other where it is 100% renewable by 2040. The impacts on price, system shortage, and emissions of the two scenarios are explored.

System Dynamics Integrated Assessment Modelling with UniSyD

Jonathan Leaver PhD FEngNZ

The taxonomy of energy modelling can be focused around six major categories, 27 subcategories and nine main archetypes. Integrated Assessment Models (IAMs) seek to model impacts of the wider economy on the energy system and are therefore usually large and complex. System dynamics models are readily adaptable to a range of applications. The system dynamics model UniSyD has been used to develop national energy systems models of New Zealand, Japan, Iceland, and Finland. These models have high transparency, capacity for high temporal and spatial resolution, fast processing times and can utilise non-linear algorithms. The UniSyD_NZ model has been developed using 13 regions in New Zealand, contains 76 sectors, 2122 primary variables and 39,186 arrayed variables, includes propagation of hydrogen infrastructure and will run on an i7 PC at 8.6 hour time intervals over 35 years in under 6 minutes.

Session Two: Short presentations on posters

Night-time Photovoltaics: An answer to the renewable energy supply-demand mismatch?

Fulton N, Jack M

Department of Physics, University of Otago

The transition to low carbon electricity is made difficult by the fact that renewable resources are intermittent, and supply often does not match with peaks in demand. Night-time Photovoltaics is a new technology concept that proposes to generate electricity from the emission of radiation from the warm Earth's surface to the cool night sky. Because night-time photovoltaics generate more at night, they could be a much better match for electricity demand. This has generated significant interest in these technologies in the research community, however, there has been little research into the limits of this technology under realistic atmospheric conditions, such as cloud cover and humidity. In this project, we investigated a range of theoretical limits: the Blackbody, Multicolour and Shockley-Queisser, of these devices with realistic atmospheric conditions. In particular, we explored the effect of varying the effective temperature of the atmosphere on the theoretical maximum power density. Our results show that under realistic conditions, the maximum power density of these devices is reduced to less than 4 W/m2. This power density is significantly less than the limits often discussed in the literature and is even less than the averaged winter output of solar PV in most locations. These results suggest that night-time photovoltaics are unlikely to solve the supply-demand mismatch problem.

Refrigerative Dehumidifier Performance Improvements using a 3D-Printed Polymer Energy Recovery Heat Exchanger

Sam Lowrey *[1,2] – sam.lowrey@otago.ac.nz
* Presenter

1 - University of Otago
2 - The MacDiarmid Institute for Advanced Materials and Nanotechnology

Domestic refrigerative dehumidifiers are a widely used home appliance that help remedy dampness issues. It is estimated that 25% of NZ homes, and 19% of US homes, have one. A recent US Department of Energy report identified fifteen technological improvements expected in domestic dehumidifiers. Two options are different forms of air-side gearing, which is the integration of an energy recovery heat exchanger (ERHX) with the dehumidifier's air-circuit. This can increase the dehumidifier's dehumidification rate and energy efficiency.

Despite the relatively low thermal conductivity of polymers, polymer heat exchangers (HXs) hold great potential as an alternative to metal HXs in a wide range of industrial applications currently dominated by metal HXs. Compared with metal, polymers are much lighter, require two times less energy to produce a unit mass of material, and most are recyclable.

In the present work, the performance of a commercially available dehumidifier, modified to operate in the ungeared mode (without an ERHX) or the geared mode (with an ERHX), has been investigated. Two ERHXs are tested: one composed of aluminium; the other is a 3D-printed polymer ERHX – both have been analysed in a recent study [1].

Performance test results will be presented for the dehumidifier, geared with either an aluminium or polymer ERHX. The results show that the geared system outperforms the ungeared dehumidifier in terms of the dehumidification rate and energy efficiency when equipped with either the aluminium, or the polymer ERHX (see Figure 1). The results will be discussed along with the future research direction.

[1] Lowrey, S., Hughes, C. and Sun, Z., 2021. Thermal-hydraulic performance investigation of an aluminium plate heat exchanger and a 3D-printed polymer plate heat exchanger. Applied Thermal Engineering, 194, p.117060.

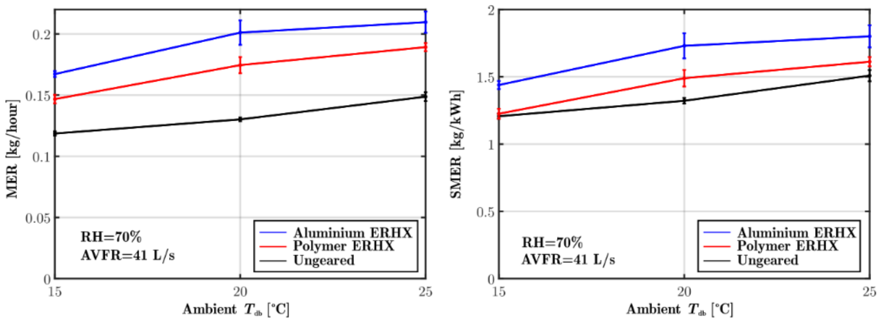

Figure 1: Prototype refrigerative dehumidifier performance measurements. Measured moisture extraction rate (dehumidification rate, left) and specific moisture extraction rate (energy efficiency, right) vs. ambient temperature for an ambient relative humidity of 70%. The air volume flow rate was fixed at 41 L/s.

A copper electrocatalyst for H_2 production from a neutral water solution

Michael S. Bennington,[1,2] Johan Hamonnet,[2] Abdullah M. Abudayyeh,[1] Vladimir Golovko,[3] Aaron T. Marshall*[2] and Sally Brooker*[1]

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Green hydrogen production, alongside reducing or capturing carbon emissions and recycling them, will be key components of a net-zero carbon future.[1,2] Hydrogen is already an established industrially important *chemical*, e.g. for fertilizer production, and will become more so as we move to decarbonise our industries (eg. move towards green steel production). Hydrogen is also likely to become increasingly important as a *fuel* in heavy transport applications, via fuel-cell technology, and as a potential replacement in many natural gas applications (eg. heating and cooking). But, unfortunately, currently over 95% of H_2 produced globally is 'brown or grey' as it originates from fossil fuels, whilst less than 5% is considered 'green' as it is produced from water by electrolysis driven by renewable electricity. Thus, moving to a zero-carbon hydrogen economy requires a move from brown to green H_2 production.

Here we present an update on our copper electrocatalyst which was previously shown to be active for H_2 production in non-aqueous solution;[3] revealing that it is very active in neutral <u>aqueous</u> solution.

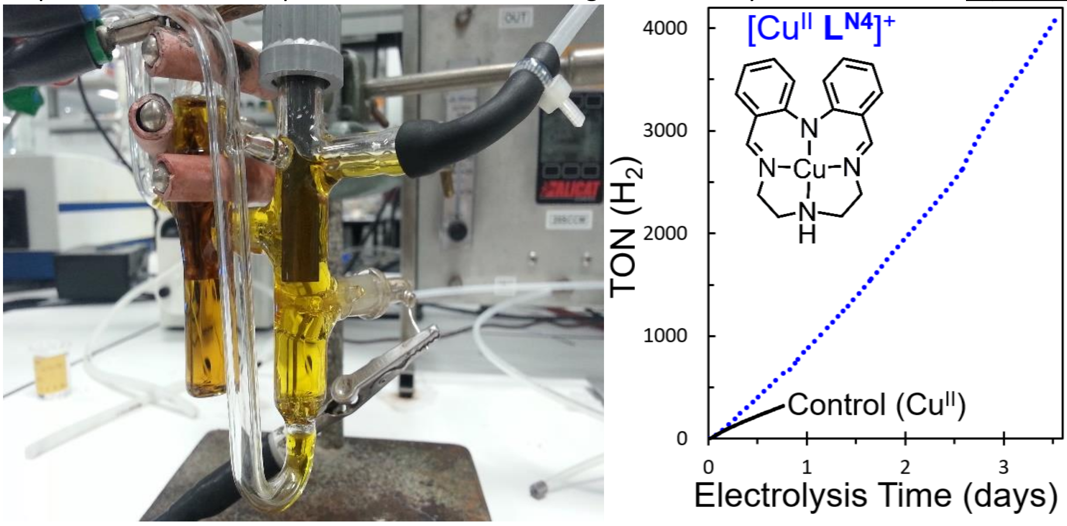

Figure: An early cell design (**left**) and the measured aqueous electrocatalytic activity of the copper catalyst (**right**)

Acknowledgements: We are grateful to the Universities of Otago and Canterbury, the MacDiarmid Institute, and MBIE for supporting this research.

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[2] Venture Taranaki and Tapuae Roa, 'H_2 Taranaki Roadmap Update', New Zealand, **2021**, https://www.venture.org.nz/assets/Uploads/H2-roadmap-update-Spring-2021.pdf (accessed October 2021).

[3] A. M. Abudayyeh, O. Schott, G. S. Hanan and S. Brooker, *Inorg. Chem. Front.*, **2021**, *8,* 1015-1029.

Condensation-frosting investigation on coating-free topographic wetting gradients for heat transfer surface applications

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Condensation-frosting is a common phenomenon across various heating, ventilation, and air conditioning (HVAC) systems. Surface coverage of condensation or frost can present a heat transfer resistance between the surface and the surrounding air, often an integral component of system's operation. Condensation on hydrophilic surfaces tends to form a film, and droplets on hydrophobic surfaces. Dropwise condensation results in greater heat transfer than filmwise. The reduced energy expenditure resulting from a decreased need to defrost and/or remove condensation from heat transfer surfaces reduces the operational cost of the system. As such, the development of heat transfer surfaces with anti-frosting qualities has become an area of interest.

In the present work, aluminium surfaces with coating-free topographical wetting gradient micropatterns, are investigated for the microdroplet growth mechanism, frost wavefront propagation and heat transfer coefficient, and are compared against control (flat) surfaces. Previous work on gradient surfaces has found that in-plane forces acting on droplets with diameters below the capillary length result in spontaneous droplet motion. It is thought that this will enhance surface water management by removing condensed droplets at smaller radii and hinder the propagation of a frost wavefront across the surface. The surfaces can therefore be important for heat exchanger applications.

We will present the current results from our experimental investigations into condensation on polished control aluminium, including the image processing methodology that allows the generation of growth curves which track average droplet radius as a function of time, and the construction of a wind tunnel to test for condensation-frosting conditions.

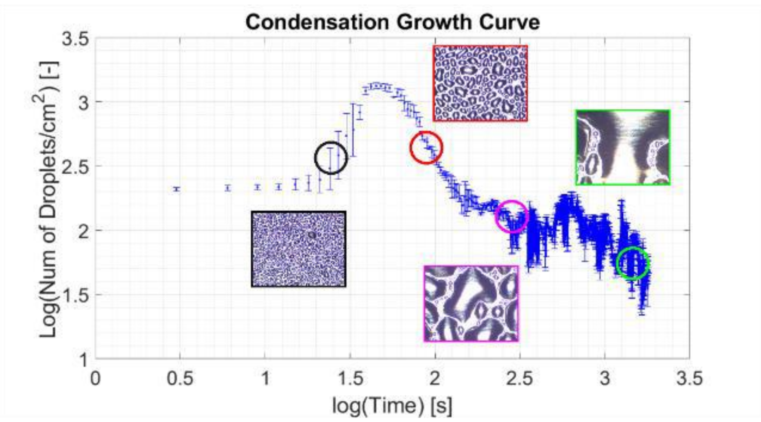

Figure 1. Log-log plot of the number of condensate droplets (averaged over 3 tests) on a surface vs. time. Top-down images of surface condensation at four points as the surface is cooled below dew point are highlighted.

Wetting Phenomena on 3D-Printed Heat Exchanger Surfaces

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Natural systems, such as rice leaves or feathers, have evolved effective and efficient water draining mechanisms because of their micro/nanopatterned surfaces. Such surfaces in heat exchanger technology could lead to enhanced dehumidification and heat transfer rates. This research aims to mimic the water draining properties of these natural systems using Fused Filament Fabrication (FFF), 3D-printing. FFF works by melting thermoplastic and depositing it in a layer-by-layer fashion. The resultant geometry is like that found in nature. The main advantage of FFF microfabrication is that it allows rapid investigation of full micropatterned heat exchanger systems. Such micropatterning in metal heat exchangers by comparison is expensive and time-consuming.

In the present work, we investigate the full 3D-print layer-height range (0.05 – 0.5 mm) to determine the corresponding range of wetting properties available on 3D-printed surfaces. Surface geometry has been characterised using scanning electron microscopy. Surface wetting properties have been characterised using: (A) goniometry, providing static/dynamic water droplet contact angles; (B) tilt angle experiments, providing the angle at which incipient droplet motion occurs; and (C) dynamic dip-testing, providing an understanding of the 3D-printed micropatterns water shedding capability (see Figure 1).

We will present these experimental results, providing the full range of wetting properties available via control over the 3D-printing method's layer-height, along with corresponding geometry for optimum water shedding. We will also detail the next stage of this work which builds on a recent demonstration of a 3D-printed polymer heat exchanger used for energy efficient dehumidification applications [1].

[1] Lowrey, S., Hughes, C. and Sun, Z., 2021. Thermal-hydraulic performance investigation of an aluminium plate heat exchanger and a 3D-printed polymer plate heat exchanger. Applied Thermal Engineering, 194, p.117060.

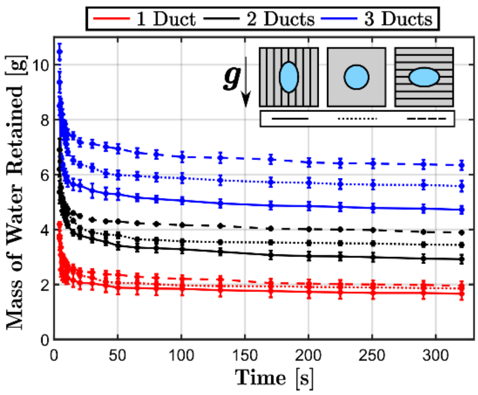

Figure 2: Water mass retained vs. time. Red represents a single duct; black represents two ducts and blue represents three ducts. Solid line - microlines parallel to gravity; dashed line - microlines perpendicular to gravity; dotted lines – smooth control surface.

Session: Three

Modelling the Long-term Impacts of Increased Demand Response within a 100 % Renewable New Zealand Power System

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Meeting peak demand is a challenge in the New Zealand power system. This will become increasingly difficult with the imminent move to 100 % renewable electricity supply due to the variable nature of renewable generation. A simple and economic approach that can assist with supplying peak demand is to use demand response (DR) at times when the power system is under stress (i.e. when demand is high).

In this study, the long-term impact of DR in New Zealand for a 100 % renewable power system has been explored using the LPCon model, owned by Meridian Energy Ltd. This linear optimisation model balances the energy flows of the New Zealand Power System to find the least cost solution to meeting demand and has the predictive ability to model scenarios from 2018 to 2048.

An iterative approach was used to increase DR in the simulated power system, where the offer price of DR was reduced and the offer volume (in MW) of DR was increased until a scenario of 20.5 % peak demand reduction for one peak hour was achieved. Comparing to a base case where 100% renewable electricity is achieved by 2030, the results showed that increased DR all but eliminated system shortages, increased the efficiency of the system by 18 %, reduced generation capacity by 1500 GWh (i.e. reduced overbuild), and reduced volatility of the price of electricity significantly. These results strongly support the role of increased DR in New Zealand's future electricity system.

What happens to demand after households adopt PV?

Carsten Dortans[1], Janet Stephenson[1], Michael Jack[2], Ben Anderson[3]

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Distributed solar photovoltaic (PV) is gradually becoming a more cost-effective technology and is popular with NZ households. It can contribute to the shift to a net zero carbon economy by enabling households to generate electricity from a renewable energy source.

However, if PV adoption continues at pace, it will eventually have non-negligible implications for the future of New Zealand's electricity grid because it may change both the amount of electricity required to be supplied from the grid and the timing of electricity demand. However, international studies are ambivalent about the likely scale of these changes, and most semi-quantitative studies to date are based on self-reports.

This research attempts to fill this international and NZ knowledge gap by bringing together quantitative consumption data from before and after-PV adoption (the 'what') together with what is happening in the households to cause these changes (the 'why').

A unique smart meter data set provides information on half-hourly electricity consumption prior and post PV adoption for 182 residential households. This data illustrates changes in total demand and in the timing of demand and enables us to explore how this varies across the households. To explore reasons for this change, interviews with a subset of the 182 households were conducted to identify changes in their energy culture. In combination, this qualitative and quantitative data provides a better understanding of the impacts of adopting PV.

We present preliminary results on the impacts of adopting solar PV in residential households and discuss emerging challenges and opportunities associated with it.

Session: Four

Spontaneous droplet motion on micropatterned aluminium for improved efficiency of heat-exchangers and wind turbines.

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University of Otago, New Zealand
Andrew Sommers
Miami University, USA

Nature has evolved a number of impressive water management solutions. The most cited and well-known example is the super water repellent lotus leaf. Behind this "magic" property are random microscale bumps with superimposed nanoscale hairs forming a hierarchical structure. Some spiders create spindle-knot/joint couplings on their web, providing a surface tension gradient that can passively transport sub-millilitre droplets without external forces such as weight force. In the current industrial era humanity is relying on metals and their alloys for numerous applications. The main issue is that metals are hydrophilic, having strong adhesion during liquid-solid interaction. The most established way to eliminate it is to hide the metal surface under a lower surface energy coating.

Inspired by nature, we have engineered passive gradient surfaces, that imitate the lotus leaf's superhydrophobicity and liquid transport properties of some spider silk. Such a coating-free surface could be made on a metal via one-step industrial methods, such as, micromilling and laser ablation. Such a surface can promote dropwise condensation over film-wise, improving water droplet removal, and spontaneous motion of certain sized droplets.

We will present a theoretical explanation, the modelling procedure and a survey of micro/nanofabrication approaches to produce microstructures with fixed- and variable-pitch, and results which clearly demonstrate passive gradient-driven droplet motion on theoretically designed and micro/nanoengineered, all-metal, hierarchical superhydrophobic gradients.

These surfaces can potentially enhance heat exchangers by improving the air-side heat transfer coefficient, and/or promoting delay (or elimination) of ice-/frost-formation under extreme weather conditions, which may be beneficial for wind turbine blades.

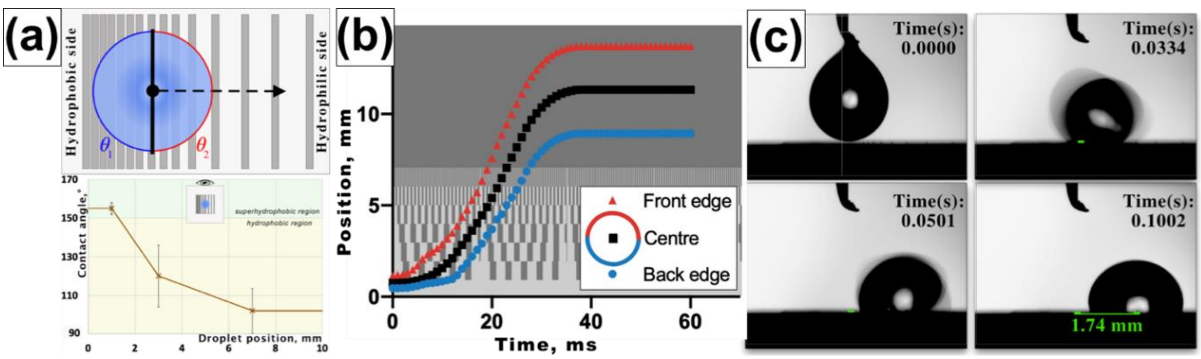

Fig. 1. (a) schematic of the linear wetting gradient (upper) and wetting properties of the gradient (lower); (b) results of numerical modelling of a 7 µL droplet on a stipe-based gradient; and (c) observation of spontaneous droplet motion on a coating-less aluminium surface with topographical linear gradient.

Considering Material Cycles for a Transition to Low-Carbon Energy Systems in Aotearoa – New Zealand: a Systematic Review

Isabella Pimentel Pincelli, Alan C. Brent, James (Jim) Hinkley
Sustainable Energy Systems, Faculty of Engineering, Victoria University of Wellington, New Zealand.

The decarbonisation of energy systems plays a central role in climate change mitigation strategies. Yet, the implementation of new energy infrastructure increases material demand, especially metals, and poses a challenge with managing their end-of-life. However, it is not yet clear to what extent integrated analyses of energy and material systems have been undertaken for the New Zealand context. This paper provides a systematic literature review to inform how material analyses have been incorporated in the planning of low-carbon energy systems in New Zealand. The results show that research efforts have forecasted low-carbon energy systems and modelled some of the infrastructure required, as well as the associated lifecycle emissions considering scenarios of different renewable electricity mixes and of improvements in energy efficiency. However, material systems – whether virgin material demand or implications for recycling– have not been considered in low-carbon energy pathways for New Zealand. We recommend energy and material systems analyses for New Zealand should become more integrated to inform better policy and decision-making. This could be achieved by developing a model that integrates energy system modelling with dynamic stock-flow models and prospective lifecycle analysis.

Keywords: energy system; material system; climate change mitigation; metal demand; lifecycle

EROI analysis of net zero transition modelling for New Zealand

Solis Norton
Mansford Station

Our planning toward net zero emissions in 2050 relies on economic modelling and assumptions about resource use. Actual resource flows are critical to these economic assumptions, energy in particular.

This paper describes a high level energy analysis of the TIMES-NZ model 'Tui' scenario model output. It uses a method known as Energy Return On (Energy) Investment, drawn from thermodynamics.
It highlights potential transition challenges and opportunities related to energy resources that are not evident from an economic perspective.

This analysis was recently presented to the International Society of Biophysical Economics in New York. Their feedback has refined results presented below.

The key points are these.

Firstly, a stronger thermodynamic understanding of New Zealand's energy delivery systems would help refine our transition path. In particular, the energy return on investment of wind-based energy. A ten-fold increase in this source of energy is a key part of transition.

Secondly, the energy return on investment of bioenergy options needs more thorough analysis. Bioenergy options also play a critical role in our transition. They are a major opportunity for the agricultural sector whose current perception of forestry is as a threat.

Thirdly, the overall impact of transition on energy use per capita and the relationship between this and gross domestic product (GDP) need full and transparent discussion. This analysis contrasts our projected transition with trends in energy use and GDP over the past fifty years. The 'Tui' scenario describes a decline in energy use per capita by 2050 to levels seen in the 1980s.

Economic projections of transition must sit well within the biophysical limits of our resource base and natural systems. Here we demonstrate how this can be successfully achieved.

Firm-Level Barriers to Geothermal Power Project Development in New Zealand

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This study brings together the empirical information on barriers for geothermal power project development in New Zealand. Special attention is paid to understanding how these barriers are internalised by project developers and financiers in their investment decision-making processes. Flat electricity demand growth (2011-2019) that is exacerbated by the potential demand loss of 13% nation-wide (i.e., from the possibility of Tiwai closure) are the major barriers that restrict decisions to undertake new geothermal projects. An important characteristic of geothermal projects is their high upfront capital costs, making the projects high-risk. This situation influences the developers' confidence to borrow a large amount of capital from the banks. For major power generators who are vertically integrated with power retailers, access to finance is not so much of a barrier as their market capitalisation and portfolio diversification have allowed them to raise the capital through *corporate finance*. However, for other project developers who sell their electricity under contract with retailers, access to finance and difficulties to secure Power Purchase Agreement (PPA) are significant barriers. For developers without a customer base, lack of PPA generates unpredictable cash flow—something that banks indicated as the biggest impediment to finance, particularly through *project finance* which is a common financing mechanism for these developers. Overall, this study offers a fine-grained understanding of barriers in geothermal project development across different types of developers that would allow policy makers to precisely identify interventions needed to address them, instead of relying on generic policy measures that may not be universally accepted.

Keywords: New Zealand; geothermal power investment; energy finance

DAY TWO

Session: Energy-efficient housing

Simulating the consequences of a residential emissions based carbon levy at the city and neighbourhood scale

Dr Ben Anderson, University of Southampton (b.anderson@soton.ac.uk)

There is increasing agreement that reducing energy demand by increasing the energy efficiency of buildings and especially dwellings in most nations is a crucial part of a transition to net-zero emissions by 2050. Yet this is also recognised as requiring significant capital investment with estimates in the order of £250-300 billion for the United Kingdom (Climate Change Committee 2020).

At the individual dwelling level, anticipated costs of retrofitting 'to an appropriate standard' range from £13,300 for a relatively efficient property to £26,800 for the most inefficient ('English Housing Survey 2018: Energy Report' 2018) although these values hide substantial and significant heterogeneity due to the variations in existing built form. Currently the cost of dwelling emissions is largely externalised to the environment and so there are few incentives for high emitters to change.

This paper explicitly links these two strands by asking whether a locally hypothecated carbon levy could realistically pay for the housing stock retrofit required in that local area. This approach responds to the summary of the recent UK Carbon Tax consultation which noted that "revenues from a Carbon Emissions Tax should be redistributed as dividends across the economy" (HM Revenue & Customs and HM Treasury 2021). In the case of this paper the redistribution is specifically for energy efficient upgrades of the existing dwelling stock. In this instance the levy would act both as an incentive to reduce household level emissions and as source of energy efficiency investment capital.

This paper simulates the consequences of a notional carbon levy applied to 1) all estimated residential consumption emissions and 2) all residential gas and grid electricity related emissions for the City of Southampton. The value of the levy is estimated for the whole city and for neighbourhoods at the Census LOSA level (~ 1,500 households) using recently published 'official' carbon values. The levy is then set against an estimate of the cost of retrofitting energy efficient dwellings in each LSOA. The models show that highly emitting LSOAs, which are generally those with least deprivation, would raise sufficient levy to retrofit their dwellings within 3 years if an 'all emissions' levy were applied. This is not the case in low emissions LSOAs which tend to be those with the highest deprivation. Here it could take up to 60 years to meet the retrofit costs if the levy was only raised on energy emissions. Redistribution to transfer levy from the least deprived but highly emitting neighbourhoods to the more deprived but least emitting would therefore be key.

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Understanding energy efficiency benefits of insulation and heat pump retrofits using smart meter data

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Over the past 12 years the Energy Efficiency and Conservation Authority (EECA) has implemented a number of retrofit programmes designed to help Kiwis live in warm and dry homes. Eligible households were retrofitted with insulation and heat-pumps with the twin goals of improving energy efficiency and improving the health and wellbeing of the occupants.

Vector has collaborated with EECA to model and analyse the electricity savings from a representative sample of retrofits. Vector Metering's smart meter data was combined with EECA's household retrofit data from the Warm Up New Zealand (WUNZ) and Warmer Kiwi Homes (WKH) programmes under an NDA and anonymised for analysis. Data privacy is paramount when handling address and smart meter data, and all processes and reports are designed to ensure data is secured, aggregated, and anonymised. No demographic details of the households were included in the dataset or any surveys: it consisted only of the smart meter data with a flag and date denoting if and when the ICP number had received a retrofit or not. Furthermore, data shared between EECA and Vector was stipulated to only be used for the project discussed in this paper, with only the aggregated anonymised results able to be published.

To analyse the electricity savings this work applies the CalTRACK methodology[1]; a simple and robust method to model the avoided electricity use of retrofitted households. Each individual household's electricity usage is modelled against the external temperature by fitting a piecewise linear regression around optimised heating and cooling balance points. A separate model is created for both the year prior to the retrofit and the year after the retrofit. These models are applied to a typical meteorological year (to compare like with like), and the results are used to calculate the avoided electricity use. The changes in electricity use of the retrofitted households are compared to a control sample selected by region and energy profile to account for the impacts of COVID lockdowns and help address macroeconomic changes.

Insulation alone showed an average saving of 1.08%, compared to the year prior to the installation. When compared to the control sample (whose usage increased year on year) the savings were larger at 2.44%. The timing of heat-pump retrofits largely overlapped with COVID-19 impacts so couldn't be accurately compared to their prior year's usage. The heat-pump analysis relied on a comparison to the control sample which showed a decrease in electricity used for heating and an increase for cooling.

The results indicate that while the average savings are relatively small they are significantly affected by time of year, baseline usage and ambient temperature in a manner which is suggestive of takeback. Additionally, the changes varied across different regions and groups; tenanted/owner occupied, and by programme (WUNZ and WKH). These conclusions inform projections of household energy use and can be used for network planning and management.

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[1]https://www.caltrack.org

From Hearth to Health: An investigation into the health impacts of the Warm Up New Zealand home insulation subsidy programme

Authors: Caroline Fyfe (University of Otago Wellington, Motu Research), Dr Lucy Telfar Barnard (University of Otago Wellington), Professor Philippa Howden-Chapman (University of Otago Wellington), Professor Jeroen Douwes (Massey University)

Background: Most New Zealand homes are cold by international standards and do not meet the World Health Organization recommended minimum indoor temperature of 18°C. In 2009, the Energy Efficiency and Conservation Authority established an insulation subsidy programme - Warm Up New Zealand Heat Smart (WUNZ) to provide "*warm, dry and more energy efficient homes*".

Aim: To assess whether residents experienced a reduction in severity and frequency of cold-associated ill health following insulation retrofits in their homes.

Methods: A dataset of houses insulated through the WUNZ subsidy programme was linked to health and socio-demographic records. A difference-in-difference model compared changes in pharmaceuticals dispensed and hospital admissions. Relative risk was used to examine chronic respiratory disease incidence. Survival analysis was used to examine cold-associated mortality.

Results: There was a statistically significant lower risk of chronic respiratory disease incidence in the intervention group compared to the control group. Relative rates of pharmaceuticals dispensed for respiratory disease and hospital admissions were also significantly lower in the intervention group. There was no statistically significant improvement in survival for the intervention group except where a heater was installed alongside insulation.

Health gains for Pacific Peoples were more pronounced than for other ethnicities whilst those for Māori were less pronounced. Additional health gains were demonstrated when an energy efficient heater was installed alongside insulation.

Conclusion: Together these results indicate better health outcomes for residents with more thermal efficient housing. Interventions to improve thermal efficiency should be delivered in a manner that ensures equity of health outcomes across socio-demographic groups.

Session Two: Energy Hardship and the Transition co-organised with the Consortium of Energy Hardship Evaluation

Ministry of Business, Innovation and Employment's Energy Wellbeing Work Programme

Presenters: Ella Priest Forsyth, Mel Pande, Victoria Coad, Laurie Boyce, Sym Pandey

Energy is an essential factor for household wellbeing, however not all households in Aotearoa are able to access or afford enough energy to meet their needs. The 2019 Electricity Price Review (EPR) found that energy hardship is a pressing issue in Aotearoa, with children over-represented in households experiencing it.

The Ministry of Business, Innovation & Employment (MBIE) has been working on several initiatives to address the recommendations of the 2019 EPR. One the most important projects is the development of a nationally accepted definition and set of measures for energy hardship for Aotearoa. We are developing two interconnected definitions – energy hardship and energy wellbeing. An accepted definition will assist with designing policies and measuring progress towards improving energy wellbeing in our communities.

MBIE is also implementing two initiatives to trial different approaches to promoting energy wellbeing (Support for Energy Education in the Community programme – SEEC), and the use of renewable energy systems at residential and community levels to improve energy affordability (Public and Maori Housing Renewable Energy Fund - PMH).

In this session, we will present our work to date:

1. Overview of MBIE's energy wellbeing programme (5 mins)
2. The development of the Energy Hardship/Wellbeing definition (15 mins)
3. The evaluation of the PMH project (15 Mins)
4. The findings from the SEEC initiatives completed (15 mins)
5. Questions and next phases (10 mins)

Kāinga Ora Emissions Reduction and Renewable Energy Programmes

Presented by **Jennifer van der Merwe, Renewable Energy Lead**

Emissions Reduction plan

- Kāinga Ora is developing an ambitious emissions reduction plan to cover its urban development, infrastructure, housing and corporate activities.
- Our housing construction programme accounts for approximately 7% of residential construction, and we are the largest residential landlord in New Zealand with a portfolio of 70,000 houses.
- We are looking to leverage this scale to catalyse change towards low carbon building practices and high efficiency homes across the sector.
- We are running NZ and world leading sustainable construction innovation projects to provide us with the tools and knowledge we need to build low carbon at scale.
- This will enable us to identify the most impactful strategies, timelines for implementation, and develop overall carbon budgets and reduction targets.

Renewable energy programme:

- Fund Goals and Objectives (very brief)
- Individual homes – learnings so far from property selection process, opportunities to integrate with retrofits, operational issues/ learnings, customer engagement
- Apartment buildings – testing solution to share the solar PV electricity generated between the apartments
- Decentralised energy sharing – RFI is being prepared seeking innovative solutions to share the benefit of the excess electricity from rooftop solar PV systems between customers
- Some thoughts on programme evaluation

Session Three: Quick-fire Pecha Kucha round on Energy Hardship and the Transition

HEEP2 - Energy Insights from NZ Homes

Greg Overton
BRANZ

The Household Energy End-Use Project #2 (HEEP2) is collecting data on how, and why, energy is used in households across New Zealand. Since July 2021, HEEP2 has been recruiting households from the Stats NZ Household Economic Survey. These households will each be monitored over 12 months, using a range of instrumentation and surveys, with the final up-to-date picture of energy use being available in the Stats NZ Data Lab. The HEEP2 data will allow researchers to answer a whole raft of questions, with the aim of understanding how to enable and motivate people to affordably create healthy home environments, in ways that contribute to a low-emissions economy.

For more information visit **www.branz/co/nz/heep2**

An overview of the “Warmer Kiwis Study” – an empirical impact evaluation of the Warmer Kiwi Homes Programme.

Caroline Fyfe
Motu

Motu will provide an overview of the Impact Evaluation of the Warmer Kiwi Homes low-income home retrofit programme delivered by EECA. The study, which monitors treated households over two winters, seeks to better understand the impact and effectiveness of the programme, in particular installation of heat pumps into living rooms. The study is also looking closely at behavioural influences and the programme’s wellbeing impacts. A summary of methods and some practical lessons learned after the first winter and monitoring during Covid-19 lockdowns will be shared.

Energy hardship, decarbonisation, and flax-roots innovation.

Scott Willis, Chris Rosenbrock, Nina Campbell
Authors affiliations: SW (Climate Navigator), CR (Aukaha), NC (EECA).

The Energy Hardship Expert Panel was appointed on September 9 this year to recommend policy priorities and actions to government. The Productivity Commission meanwhile is preparing an inquiry looking at the drivers of intergenerational deprivation. We all know that improved housing quality leads to better health outcomes and can alleviate energy hardship while providing jobs and community wellbeing. Energy hardship and poor quality housing is still rampant in Otago however, particularly among whānau and Pasifika and migrant communities, and despite ongoing community efforts to ensure Otago homes are warm and cosy.

Back in 2009, EECA piloted a new programme to address energy hardship in Otago through the Waitati Energy Project Retrofit Project. That pilot informed the Warm Up New Zealand: Heat Smart programme and also delivered heavily subsidised insulation to more than 400 Otago homes in just over 4 months. Fast forward to 2021 and another Otago pilot, to expand upon the Warmer Kiwi Homes programme in partnership with EECA, is being prepared.

The Energy Hardship Evaluation Consortium was initiated in 2020 to enable a collaborative approach to defining best practice in measuring the impact of projects like this one in eliminating energy hardship. How might the Otago based pilot, aligning with existing local programmes, inform and empower national energy hardship programmes? Our presentation details the collaborative design process, the pilot goals, whānau approach and material elements in the context of the Climate Change Commission's recommendations for emissions reduction.

Community Resilience and Energy Security Research at GNS Science

Smrithi Talwar
Senior Social Scientist, GNS Science

As New Zealand's 'Energy CRI', GNS Science research enables the country's transition to a low carbon emissions future. Several researchers within the organisation are involved with work that contributes to a better understanding of equity considerations in this transition, contributing to the New Zealand government's 'Just Transitions' vision. Some examples of work that interfaces with the Treasury's LSF and wellbeing indicators, or that seeks to throw additional light on energy security/ hardship are the following:

- Scientists at GNS are increasingly interested in issues related to the energy security and energy resilience of isolated communities. We are working with a rural marae (Ngahina ki Ruatoki) on a self-sufficient microgrid for their community, and with DOC to support robust renewable energy solutions for some of their more remote locations.
- GNS has worked with Janet Stephenson to use the Centre for Sustainability's Energy Cultures Framework to a project on residential heating from geothermal in Taupo. A paper evaluating this work using the Treasury's wellbeing framework will be presented at the upcoming NZ Geothermal Workshop in Wellington.
- A proposal to the Deep South National Science Challenge (under their decision making under uncertainty workstream) models the impact of climate scenarios on community resilience indicators in the Hawke's Bay region. This work has wider applicability across GNS's science research. Several colleagues working on energy security/ hardship are involved with the thinking behind this proposal.
- An ongoing project is developing an in-house methodology to assess the impact of GNS Science's projects on community resilience and draws from Indicators Aotearoa. This work will help us to eventually monitor and evaluate the societal impact of the organisation's energy research.

Tackling hardship - an industry perspective

Miranda Struthers
Accessible Energy Advocate
Electricity Retailers' Association

Energy hardship is a complex issue. It's not just about energy price but low incomes, poor housing quality, inefficient appliances and low energy literacy. These are all contributing factors and we need to be tackling all of these to lift New Zealand families out of energy hardship.

Electricity retailers have sharpened their focus on this important issue and have been working hard to provide greater support to customers who struggle to heat their homes or afford their energy bills. Collaboration between industry, government and the community sector is critical to shifting the dial on energy hardship.

In 2018 the Electricity Price Review indicated that more than 100,000 kiwi households are in energy hardship. The electricity sector wants to do its part to make sure that whānau in vulnerable circumstances can keep warm, dry, and healthy.

ERANZ is leading its members in finding impactful and creative solutions to help keep customers connected and top of their bills. We've established an energy coaching programme, EnergyMate, a free community-based service which is now in 13 locations across NZ. We're building stronger connections with the community sector and have been working with the Electricity Authority and others on the Consumer Care Guidelines. There's still more to be mahi to be done to achieve energy equity as we transition to a zero-carbon future. ERANZ and our members are committed to being part of the solution.

Aotearoa Community Renewable Energy
Design of an Impact Framework

Ryan Roberts, Alan Brent, Jim Hinkley
Sustainable Energy Systems, Victoria University of Wellington

A session was held on the 15th of September at the Community Energy Network to inform the design of a community renewable energy (CRE) impact framework. It was attended by community development practitioners and specialists in the sector, with the main talking points being:

1. Discuss the main objectives of CRE projects
2. Possible indicators, metrics, or suitable approaches to convey these impacts.
3. Appropriate data collection, monitoring and an evaluation method.

From this, a draft impact framework has been created and will be adapted further through interviews with community members in the field.

Maximising the Impact of Our Work

Gareth Cartwright
Executive Officer of Community Energy Network

The Community Energy Network is comprised of 17 members from across the country - literally from Kaitaia to Bluff - who are community enterprises focussed on eliminating energy hardship and supporting the transition to low carbon resilient communities.

Over the last 3 years we have moved to extend our impact to include critical parts of energy hardship and transition resilience. This includes:

- Housing quality and thermal envelope with 7-10,000 homes insulated and/or heated every year over the last 15 years. This includes well over 250,000 homes assessed and thousands of community workshops. We are also advocating for a much larger set of home quality interventions to ensure no home is left behind.
- Establishing and launching a home sensor and reporting system in partnership with Monkeytronics.
- Collaborating with a community enterprise in Raglan to run a pilot for community led renewable energy generation, storage, and management
- Supporting the Sustainability Trust to pilot an energy retailer service that has removal of energy hardship using all the above plus the potential use of a community hedge to provide the cheapest possible energy.

This talk will explain why CEN has broadened its focus to include all key drivers of energy hardship while also focussing on improving the measurement of our impact. Developing a robust Impact Framework, including quantitative and qualitative measures, is going to be critical to ensure policy and funding decisions in the future are well directed.