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## Keynote presentations

### **Keynote 1 | Low Carbon Energy Systems for APEC Sustainable Cities**

Professor Li Zhu, *Tianjin University, China*

Professor Zhu's presentation will include 6 parts: 1 Cities in Asia-Pacific Region, 2 Initiatives to Sustainable Urbanization in APEC, 3 Towards Sustainable Cities, from Models to Reality, 4 Low Carbon Transition of Energy Systems is the Way, 5 Technology Innovation and Development is the Key and 6 Brief on APEC Sustainable Energy Center.

### **Keynote 2 | Determinants of Well Being: Energy and Environment in Rural Maori Communities**

Dr Guy Penny, *EMPlan Services Ltd, NZ*

Our well-being is affected by many factors, including our dynamic relationship with the environment, which is increasingly mediated by the outcomes of urban and spatial planning. In this talk, the determinants and dimensions of well-being are presented and illustrated through two collaborative research projects with rural/remote Maori communities. One project finds that changes in the relationship with the marine-aquatic environment has had significant impacts on individual and community well-being (hauora). The other project uses a collaborative action-research approach to introduce renewable energy technologies into two Maori communities to improve quality of life and cultural resilience, and explore development options. In the context of this session, there are lessons about research processes and well-being for urban planning and regeneration activities, and for all of us.

### **Keynote 3 | The Benefits of Sustainable Design at the Neighborhood Scale**

Professor Harrison Fraker, *University of California, Berkeley, USA*

This presentation explores an integrated 'whole-system' design approach at creating resilient and resource self-sufficient neighborhoods. It presents highlights from a 15 year effort by the author, including the original formulation of the 'EcoBlock' concept, the examination of first generation efforts at sustainable neighborhood design, a current effort of applying the "EcoBlock" concept as a retrofit strategy to an existing neighborhood and ultimately a discussion of the environmental performance of the public realm in creating healthy, more sustainable and aesthetically pleasing neighborhoods.

**Keynote 4 | Housing: Homes or Energy Sinks**

Dr Kay Saville-Smith, *CRESA, NZ*

This reflects on the extent to which dwellings provide us the context for home or creates an energy sink. It reflects on the meaning of home, the functions of dwelling as a mediator of the bio-physical environment and patterns of energy consumption associated with the refocusing of the building industry in New Zealand away from affordable house production to higher quartiles of value.

**Keynote 5 | 1.5C global warming: can we still get there? Insights from the IPCC's recently published special report**

Professor Diana Ürge-Vorsatz, *Central European University, Hungary*

## Parallel session presentations

### **[E006] Multi-stage optimization of local environmental quality by comprehensive computer simulated person**

Dr Sung-Jun Yoo, Professor Kazuhide Ito, *Kyushu University*

Previously, we have developed a comprehensive computer simulated person (CSP) that integrates computational human model (virtual manikin) and respiratory tract model (virtual airway). Moreover, an inclusive prediction method was established by integrating computational fluid dynamics (CFD) analysis with advanced CSP which is combined with physiologically-based pharmacokinetic (PBPK) model, thermoregulation model (2-node model proposed by Gagge et al.) for estimation of indoor environmental quality targeting micro-climate around human body and respiratory area with high accuracy. In contrast with the previous researches concerning independent prediction of indoor air quality (IAQ) and respiratory exposure, we suggested comprehensive method that can estimate not only the contaminant inhalation but also constant interaction in the contaminant transfer between indoor spaces, i.e., a target area for IAQ assessment, and respiratory zone for health risk assessment.

In this study, we focused on the usage of the CSP as an air/thermal quality sensor in indoors, which means the application of comprehensive model for assessment of IAQ and thermal environmental quality. Demonstrative analysis was performed in order to examine the applicability of the comprehensive model to the HVAC control scheme. We assumed CSP stood at the center in the simple model room which has dimension of 3m×3m×3m. Formaldehyde which is generated from floor material was assumed as a target contaminant, and flow field, sensible/latent heat and contaminant transfer analysis in indoor space were conducted by using CFD simulation coupled with CSP. In this analysis, thermal comfort was evaluated by thermoregulatory analysis, and respiratory exposure risks represented by adsorption flux/concentration at airway wall surface were estimated by PBPK-CFD hybrid analysis. These Analysis results concerning IAQ and thermal comfort will be fed back to the HVAC control, and could be used to find a suitable ventilation rate and energy requirement for air conditioning system

### **[E008] Retrospective study of cold indoor temperature and healthy life expectancy among community-dwelling older adults**

Yukie Nakajima, Mari Ono, Dr Shintaro Ando, Emeritus Professor Tanji Hoshi, Professor Toshiharu Ikaga, *Keio University*

**Background:** The Japanese population is ageing, and a growing number of people need long-term care. There is a gap between life expectancy and healthy life expectancy, and closing this gap is an important public health goal. Cold-related health problems among older adults, such as higher blood pressure and lower physical performance, have been attracting attention. Against this background, the aim of this study was to investigate the relationship between perceived indoor temperature in winter and risk of certification of long-term care need, which indicates shorter healthy life expectancy.

**Methods:** This retrospective study involved 205 community-dwelling older adults living in Japan. Participants completed a self-report questionnaire about personal characteristics, housing, and perceived indoor temperature in their home during winter. Participants were divided into a Cold group and a Warm group based on perceived indoor temperature.

**Results:** The Kaplan-Meier method and analysis of covariance (ANCOVA) were used to examine differences between the groups in age at certification of long-term care need. The Kaplan-Meier method, a nonparametric method, showed that healthy life expectancy was shorter in the Cold group than in the Warm group. In multivariate analysis by ANCOVA, there was a significant main effect of perceived indoor temperature, with the Cold group having a younger age at certification of long-term care need ( $F(1, 213)=7.99, p=.005$ ). Estimated marginal means indicated that healthy life expectancy was 3.43 years shorter in the Cold group than in the Warm group.

**Conclusions:** Perceived cold was associated with shorter healthy life expectancy. These findings suggest that policies that support older adults in maintaining a warm home in the winter could help to prevent the need for long-term care.

#### **[E010] Performance analysis of a novel solar-driven absorption refrigeration system with LiCl-H<sub>2</sub>O and LiBr-H<sub>2</sub>O working pairs**

Professor Yonggao YIN, Mr LI Teng, Professor ZHANG Xiaosong, *Southeast University*

Absorption chillers have significant potential to utilize low-grade thermal energy with natural refrigerants. A solar-driven absorption refrigeration system was investigated for the development of novel low-grade heat-driven absorption cycle and to be well combined with low-cost flat plate solar collectors. The two-stage absorption cycle works with LiCl-H<sub>2</sub>O in high-pressure solution cycle and with LiBr-H<sub>2</sub>O in low-pressure solution cycle. The solar-driven absorption refrigeration system was constructed using a mathematical model, which took into consideration the implementation mode of falling film type for both absorber and generator. Under the nominal working condition, the effects of solution mass flow rate on the absorption cooling subsystem performance were evaluated. The recommended value of solution mass flow rate is around 0.03 kg·s<sup>-1</sup> in this study. Furthermore, the hourly operating performance of the proposed system in a typical summer day of Nanjing was presented. According to the simulation results, the cooling capacity can be achieved as high as 9.3 kW, and the average values of chiller COP and water storage tank are 0.41 and 58.6 °C, respectively. Moreover, the novel absorption system presents cooling capacity enhancement by 21.1% compared to the conventional two-stage absorption system on average for the nominal working case. For the temperature of water storage tank through the comparative study, the maximum reduction of 4.2 °C could be reached in the novel absorption system. This study is helpful to design and understand the operation characteristics of such kind of solar-driven absorption system.

## **[E012] Field Survey of Medical History and Use of Kotatsu Heating in Winter among Older Adults in Japan**

Mari Ono, Yukie Nakajima, Saeka Shiraishi, Misa Matsumoto, Professor Toshiharu Ikaga, *Keio University*

**Background:** In Japan, the number of people who need nursing care has more than doubled from 2000 to 2012 and medical expenses tend to increase yearly. In addition, demand for home care is high, and the indoor thermal environment of houses where older adults spend most of their time is important. Japanese houses are often cold in winter because of poor insulation, and older people tend to use the “kotatsu” heating system, a table with an electric heater attached to the underside that produces localised heat. The objective of this study was to investigate the relationship between medical history and use of the kotatsu heating system in winter among older adults in Japan.

**Methods:** Participants in this study were 107 community-dwelling older adults using rehabilitation facilities in Kochi and Yamanashi Prefectures, Japan. Standardised questionnaire surveys and indoor temperature measurements were conducted in winter of 2017 to assess participant health and housing characteristics. At the same time, nursing care records from rehabilitation facilities were collected by copying with a camera.

**Results:** Multiple logistic regression analysis was conducted using each medical history item as an objective variable. Use of kotatsu, sex, age, body mass index, work experience, family size, and economic satisfaction were used as explanatory variables. Participants who use kotatsu had a lower probability of dementia compared with those who reside in houses without kotatsu (odds ratio [OR] = 0.23;  $p = .007$ ; 95% CI, 0.08-0.68). On the other hand, those who use kotatsu tended to have a higher probability of spinal cord dysfunction compared with those who reside in houses without kotatsu (OR = 2.58;  $p = .098$ ; 95% CI, 0.84-7.90).

**Conclusions:** The Japanese kotatsu heating system helps prevent diseases associated with cold exposure among older adults, but may have a negative effect on diseases related to physical function.

## **[E014] Patterns of electricity consumption in electrically heated households in the UK: Analysis of a large scale representative random sample**

Dr Ben Anderson, Dr Tom Rushby, Dr Michael Jack, *University of Southampton and University of Otago*

Patterns of electricity demand are evolving as the UK attempts to de-carbonise heat by switching electricity generation to predominantly carbon-free fuels and shifting domestic space and hot water heating to electricity through different forms of thermal storage and heat pumps. Currently very little is known about how different kinds of households use electrical heating and how new appliances such as heat pumps will be fitted into space-heating habits. Understanding the timing of this demand is particularly important as it may contribute to increased evening peak electricity demand which has both local effects on constrained lines and system-wide effects due to the increased reliance on intermittent ‘non-peaking’ energy sources. This paper applies the ‘energy cultures’ approach to the analysis of heating-related electricity demand for a large scale ( $n > 3,000$ ) representative random sample of households from the south east of England. This sample contains households with mains gas heating, electrical storage heating, heat pumps and other electrical

heating appliances together with information on other household attributes and household level 15 min electricity consumption data that has been continuously collected since 2016. The paper will present analysis of the differences in temporal (day of the week/seasonal) electricity demand profiles between dwellings with different heat and hot water sources and different combinations of 'building physiology' (e.g. number and type of thermostats, forms of insulation), occupant pro-environmental attitudes and different energy-using practices. The paper will then compare these results with similar analysis of heat pump use in 44 NZ households. This will show how different infrastructural arrangements can lead to different outcomes at the local neighbourhood and network levels. In essence, heat-pump use in NZ is likely to further exacerbate peak electricity demand difficulties whereas the UK may be able to leverage different infrastructural arrangements to store heat during low network demand periods.

### **[E020] Multi-level Analysis among Indoor Thermal Environment in Winter and Nocturia**

Kaori Nibe, Dr Shintaro Ando, Professor Toshiharu Ikaga, *The University of Kitakyushu*

Nocturia is characterized by the need to get up at least one or more times in the night to urinate. Nocturia is one of the symptoms the most decreased quality of life of all urologic symptoms. Recently, the studies on thermal environment and nocturia have reported, and previous studies have suggested that cold exposure is possible to cause nocturia. For example, Saeki et al. evaluated the relationship between the thermal environment in houses.

On the other hands, the effect of change of daily thermal temperature on nocturia has not been noticed. In this study, we examined whether the effect of room temperature on frequency of urination is instant or cumulative based on multi-level analysis. A field survey was carried out in order to measurement the daily room temperature during the winter period of about two weeks. Also, we investigated the frequency of urination from the question of diary.

At first, multiple regression analysis was performed. As a results, indoor air temperature in the bedroom while sleeping were associated with nocturia. Next, we performed multi-level analysis to analyze the influence of room temperature on nocturia in more detail. In the best model of this analysis shows that if average room temperature increases 10°C, the frequency of urination at night decrease 0.91 times. Also, this results showed that the average temperature in the bedroom during the study period had greater influence on nocturia than daily temperature in the bedroom. It suggested that cold exposure in the long term had an influence on nocturia. This result suggested that by keeping the thermal environment of the house warm, it is possible to relieve the cumulative influence to symptoms of urination. It will reduce the risk of falls when go to the bathroom. Furthermore, it can lead to relieve the risk of fractures and mortality.

### **[E021] Cost-benefit analysis of residential thermal insulation considering co-benefit from prevention of hypertension**

Yoshimasa Noda, Dr Shintaro Ando, Professor Toshiharu Ikaga, *The University of Kitakyusyu*

Recently, hypertension has become a tendency to increase across Japan. Previous studies have investigated the influence of room temperature on health however only a few studies have verified longitudinal survey. Therefore, in this study, we investigated a questionnaire, room temperature measurement, existence confirmation for a hilled rural area in Japan. Based on this, first **1)** clarify the impact of indoor thermal environment on death by cardiovascular disease in this survey. Second, **2)** reveal relationship of residential environment to Hypertension and **3)** conducted cost-benefit analysis with prevention of hypertension.

**1)** Survival rate by hypertension was investigated by Cox proportional hazard model was used data-sets from a 4-year field study. As a result, the hazard ratios of developing hypertension in the 4-year period were 5.97 times in those whose rooms were kept at  $<9^{\circ}\text{C}$  compared with those whose rooms were kept at  $\geq 9^{\circ}\text{C}$ .

**2)** This cohort study used data-sets from a 10-year field study. Logistic regression analysis was used for the relationship between the average temperature at night (midnight) and the occurrence of hypertension for 10 years. As a result, the odds ratios of developing hypertension in the 10-year period were 5.97 times in those whose rooms were kept at  $<18^{\circ}\text{C}$  compared with those whose rooms were kept at  $\geq 18^{\circ}\text{C}$ .

**3)** Based on the odds ratios, cost-benefit performance of hypertension accompanying room temperature improvement was compared in the case of high thermal insulation of a house with low room temperature and when it was not done. As a result, the required recover the initial investment cost would change from 58 to 20 years and get the benefits about 1,200 US Dollars every 10years.

This study has suggested that long-term relationship between room temperature and cardiovascular disease. Also, importance of residential thermal insulation was confirmed by reduction in medical expenses from prevention of hypertension.

### **[E022] Performance analysis of a liquid desiccant cooling system using mixed solution driven by low-grade heat source**

Professor Yonggao Yin, Miss Cheng Jie, *Southeast University*

Liquid desiccants evaporative cooling air-conditioning (LDECAC) system has advantages in removing latent load from the process air as well as reducing electrical energy consumption. The LDECAC system can be driven by low-grade heat sources, such as solar energy, and is environmentally friendly due to no use of ozone-depleting refrigerant. Six proportions of mixed solutions ( $\text{LiCl}/\text{CaCl}_2$ ) are derived from the validated mixing rule. The water vapor pressure of mixed solutions and  $\text{LiCl}$  solution is same, therefore it can be selected as an indicative factor to evaluate substitute of  $\text{LiCl}$  solution. Performance of this system using different liquid desiccants including  $\text{LiCl}$  solution and mixed solutions is compared by mathematical simulation. The results show that the dehumidification ability of mixed solution is [inferior to](#) that of  $\text{LiCl}$  solution. Besides, the increase of concentration of mixed solution leads to the increase of temperature and moisture content of supply air. This system can handle the process air to  $17.6^{\circ}\text{C}$  and  $8.9 \text{ g/kg}$  under the design condition

using 39% LiCl solution, meanwhile, the parameters of the air supply using 48% mixed solution are 20.7°C and 10.7 g/kg. It shows that the air supply can meet the requirements of maintaining the indoor environment using different liquid desiccants. Moreover, the cost of the six mixed solutions is 22.7% cheaper than that of 37% LiCl solution at least, which shows significant economization in application. Finally, energy consumption of the LDECAC system is analyzed. The energy consumption of transmission and distribution can be reduced by using mixed solution for lower density and lower specific heat capacity. It should be noted that the effect of solution viscosity was not considered in the energy consumption model. The empirical correlations of viscosity of mixed solution should be obtained through experiments and the model should be modified in the future.

### **[E023] Influence of Indoor Air Temperature on Nocturia Symptoms**

Koki Hirata, Shintaro Ando, Toshiharu Ikaga, Shuzo Murakami, Yoshihisa Fujino, Tatsuhiko Kubo, Masaru Suzuki, Shun Kawakubo, *the University of Kitakyushu*

Nocturia is characterized by the need to get up at least once in the night to urinate, and it is known that ageing increases prevalence; it is an important problem in Japan, which has an ageing population. The symptom is associated with a lower quality of life; previous studies have reported that it inhibits sleep and is a risk factor for falls and fractures. Therefore, we focused on nocturia as one of the symptoms concerning the relationship with the living environment. This research is particularly important in Japan, where increases in medical expenses are a serious issue.

In this study, we analysed the relationship between the home thermal environment and nocturia symptoms using data obtained from a survey of households receiving cost assistance for insulation renovation from the "Smart Wellness Housing Survey" that carried out by MLIT. The overactive bladder symptom score (OABSS) was used as an index to evaluate nocturia frequency. Based on this survey, approximately 53% of the target samples had nocturia symptoms. The mean room temperature in the nocturia group was significantly lower in all rooms that living room, bedroom, and dressingroom than those in the control group. A multiple logistic regression analysis showed that a colder thermal environment before going to bed is associated with a greater chance of exhibiting nocturia symptoms. Note that this result suggests that room temperature is related to nocturia, independent of age and outside temperature. This result suggested that by controlling the thermal environment of the house to maintain a mild temperature, it is possible to prevent night-time urinary symptoms from developing.

### **[E024] Study on the Cooling Load Caused by Envelope Heat Transfer of Underground Residential Buildings**

Ms. Ziyi Su, Professor Xiaofeng Li, *Tsinghua University*

With the rapid development of the economy, the expansion of major cities makes it essential to utilize the underground space rationally. Therefore, it becomes common to use underground space in shopping malls, public transportation stations and residential buildings. The underground space of residential buildings is mostly used for garages, storage rooms and some residential rooms. The

characteristics of the envelope structure are different from those of the above-ground buildings. Currently, one-dimensional steady-state simplified calculation methods are widely used to estimate the cooling load caused by the heat transfer of the envelope structure. However, the accuracy of the present simplification is far from enough.

In this paper, a three-storey underground building is studied. The three-dimensional unsteady method was used and the CFD simulation tool named PHOENICS was applied to calculate the envelope heat transfer. The influence of depth, the geometry of the building and the position of the room on the envelope heat transfer is studied.

The results showed divergence in different rooms. The three-dimensional heat transfer characteristics of shallow-buried buildings are not obvious, and therefore the two-dimensional unsteady simplified method can be applied in the estimation of cooling load caused by the underground envelope heat transfer. The one-dimensional steady-state simplified method can be applied in deep-buried buildings. In the calculation of rooms in the corner of the building, the accurate three-dimensional unsteady method should be used in that the three-dimensional heat transfer characteristics are obvious.

The results of this study give the guidance on the calculation of the cooling load caused by the envelope heat transfer in underground buildings. In further, the study will focus on the optimization method for the automatic CFD grid settings to reduce the accurate simulation time. Then the method will be attached to the building energy simulation software called Designer's Simulation Toolkit.

#### **[E025] An Investigation on indoor environment in homes of elderly residents in winter in urban area of Shanghai, China**

Professor Zhenhai Li , Professor Zhenhai Li, Ting Wu, Professor Hiroshi Yoshino, Professor U Yanagi, Professor Kenichi Hasegawa, Associate Professor Naoki Kagi, Associate Professor Tomonobu Goto, Professor Qingyuan Zhang, Associate Professor Huibo Zhang, *Tongji University*

This study intends to investigate the indoor environment in winter in homes of elderly residents in urban area of Shanghai, China. The investigation was performed from December 2016 to November 2017, including questionnaire survey and field measurement. Indoor thermal environment, the usage of heating equipment, indoor clothing habit of elderly people were investigated and analysed. Results show that the indoor air temperature of most homes were lower than the heating temperature of China Standard GB/T 18883-2002. During the investigation, the average indoor air temperature of living room, bedroom and bathroom were 13.9 °C, 14.5 °C and 13.0 °C respectively, while the average outdoor air temperature was 6.3 °C. 91.3% elderly people had air conditioner with heating function in homes, but mostly used for short time. The surveyed elderly residents worn cloth with insulation value between 1.4 clo and 3.2 clo in home, while most of them reported that their indoor thermal environments were within the comfort range. It should be noted that the acceptable indoor temperature may not reasonable for the health of elder people. More studies are needed for affirming the reasonable temperature for the long-term health of elder people.

**[E027] Indoor air quality in passive and conventional buildings in severe cold region of China**

Qingwen Xue, Professor Zhaojun Wang, Mr Zhiyi Yu, *Harbin Institute of Technology*

A field survey on indoor air quality was carried out in a newly built passive residential building and conventional energy-efficient residential buildings in Harbin. The results show that the levels of CO<sub>2</sub> were lower in passive building (PB) than that in conventional buildings (CBs), indicating a higher air exchange rate in PB. The PM<sub>2.5</sub> levels in passive and conventional households were not significantly different under a good weather condition, whereas that was significant higher in conventional households under the severe haze polluted weather condition. It is clear that during the outside air polluted period, there was a significant proportion of time with indoor pollution levels exceeding the air quality standard. The operation of air cleaner contributed to a considerable decrease of indoor PM<sub>2.5</sub> concentration. The improvement of filter efficiency is warranted for mechanically ventilated PB. And air cleaners for indoor recirculated air are highly recommended for all buildings.

**[E028] Thermal environment and thermal comfort in a passive residential building in summer and winter**

Professor Zhaojun Wang, Mr Yuchen Ji, *Harbin Institute of Technology*

A field measurement was conducted in a passive low-energy residential building in Harbin, with subjective survey on residents' thermal response. The results showed that in winter the mean indoor air temperature was 25.5°C, and the average relative humidity was 31.3%. While in summer, the mean indoor air temperature was 26.2°C, and the mean relative humidity was 59.3%. In winter, 50% residents responded the indoor environment was over warm, and they usually adjusted clothing to the environment. In summer, nearly 80% of the votes were thermal neutral, indicating that most of the residents were satisfied with the suitable indoor temperature. The thermal neutral temperatures in winter and summer were 24.2°C and 25.3°C, respectively. The residents felt dry in winter and felt wet in summer. Therefore, a lower indoor temperature was recommended in operation to improve thermal comfort and reduce energy consumption in winter.

**[E031] Thermochemical heat storage system for residential buildings: A case study**

Zhenqian Chen, Yi Wang, *Southeast University*

Thermochemical heat storage system has a great potential in solar energy storage due to its advantages of high heat storage density and long storage time. In this paper, taking Nanjing (32.0° N and 118.5° E) for example, a thermochemical heat storage system was designed based on Mg(OH)<sub>2</sub>/MgO, which can be applied in residential buildings. The heat storage and exothermic processes of the heat storage units (HSU) were investigated by numerical simulation. The third boundary condition was adopted and the temperature change of the heat transfer fluid (HTF) in the channel was considered. After modelling the whole system, some parameters of the system were optimized, such as the size of HSU, the temperature of HTF and the velocity of HTF. The results reveals that there is an optimal temperature and velocity of HTF and the optimal size of HSU is related to the difference of HTF temperature between inlet and outlet.

**[E037] An indoor formaldehyde monitoring method based on experiment and CFD simulation**

Tiankai Chen, *Chongqing University*

Real-time monitoring of indoor pollution through the sensor has been more and more used in buildings, however, there is no corresponding method to guide the monitoring method. This study will take formaldehyde as an example to explore a formaldehyde monitoring method applicable to office buildings. First, the experiment platform was set up in an office building has just newly renovated. Formaldehyde monitoring devices are placed in different locations in the room and we measured the formaldehyde concentration at different positions in room under different air distribution. Subsequently, we simulated the indoor formaldehyde concentration field with CFD according to the actual situation and verified it with the real measured value. Finally, we obtained a formaldehyde monitoring method according to the actual situation of the monitoring device, the concentration distribution of formaldehyde and the human formaldehyde exposure. This method includes: monitoring device layout method, monitoring frequency and monitoring data modification under different influencing factors.

**[E039] Tā Papa: Earth Touch**

Mr Hēnare Walmsley, *Ngāti Tuhourangi Wahiao, Whakaue/ Ngāti Hurunga Te Rangī, Te Arawa waka*

Ko au te awa, ko te awa ko au. I am the river and the river is me.

As we travel through the mindlessness of urban development throughout the world - should we be focused primarily on the individual or community beliefs of people?

This presentation contends that if an inherent order in the culture of people is evident then the effects can be translated into the way we build our countries, cities, communities and even individuals.

Anthropomorphism is the study of personalising inanimate objects into humanistic or animalistic beings. We can transform these objects into real life situations and create a narrative of how we could live, work and play. Māori understand the relationship of genealogy, ritual and environment (whakapapa, kawa and whenua) is a powerful force which pervades our very being. **Tā Papa: Earth Touch** is but a natural phenomenon.

**[E040] Smoking practices and experiences in apartment buildings in Melbourne, Australia**

Dr Nicola Willand, Dr Megan Nethercote, *RMIT University*

Homes are a key location for exposure to tobacco related pollutants. The risk of being exposed to environmental tobacco smoke even in non-smoking households has proven to be higher in multi-unit buildings. In the absence of smoke-free policies in Victoria, Australia, making rules about smoking in apartment buildings is at the discretion of the owners corporations. Research on smoking in the home in Australia is limited and focused on detached houses. However, with multi-unit housing becoming more prevalent in major Australian cities, a better understanding is needed of the links between smoking practices, environmental tobacco smoke exposure and apartment building design and management to protect public health.

This paper investigates the smoking patterns and experiences in apartment buildings in Melbourne, Australia. This qualitative study draws on semi-structured interviews in 31 households in 13 high-rise buildings ranging from subsidised housing to luxury apartments which had been completed since 2010.

Active smoking was reported in almost all buildings regardless of affordability. In general, smokers used their balconies to smoke. However, smoking inside the building was reportedly practiced by some neighbours, at times in violation of the owners corporations' rules. Non-smokers were annoyed and distressed by second-hand smoke in common areas or by smoke infiltrating from neighbouring dwellings or balconies. The prohibition of smoking inside displaced some smokers onto the street, exposing people to intense smoke when accessing the building. Cigarette butts discarded over balcony balustrades proved a common cause for annoyance.

Although limited by the small size, this study illustrates the challenge of balancing individual rights and public health concerns around smoking in apartment buildings. Future research is needed on the exposure to tobacco related indoor air pollutants, mitigation of smoke drift, and compliance and enforcement of smoke-free apartment rules to inform apartment design guidelines, public health policy and strata management practices.

#### **[E041] Healthy Homes: Using Smartphone Apps for Stakeholders and Consumers**

Professor Michael Goldschmidt, Associate Professor Gina Peek, *University of Missouri*

##### Background

The National Healthy Homes Partnership translates research into an outreach program dedicated to reducing housing deficiencies and mitigating risks. The partnership has assisted individuals, families, and professionals using a variety of educational tools (Booth & Peek, 2013), including programs, guides, exhibits, media (broadcast, print and social). In the last two years, the partnership assisted in developing smartphone apps, for the US Department of Housing and Urban Development, for use by professionals (including extension specialists), youth, and consumers.

##### Objectives

The goal of stakeholder apps is to increase knowledge of healthy homes issues for outreach programs by professionals working directly with families. The goal of the consumer apps is to increase awareness of unhealthy home conditions and suggest mitigation strategies for the hazards for families. Each app incorporates the eight guiding principles of healthy housing: dry, clean, maintained, safe, ventilated, pest-free, contaminant-free, and thermally-controlled (U.S. Department of Housing and Urban Development, 2016). These principles are widely recognized

across US federal agencies and national organizations (U.S. Department of Housing and Urban Development, 2013).

#### Smartphone App Organization

The apps provide peer-reviewed, technical information about individual hazards and directs the stakeholder to action steps to assist families. Each chapter guides the user through a holistic approach to healthy homes and the interrelated nature of each topic. These apps also include room-by-room checklists and links to additional resources from federal agencies. Users of the app are able to bookmark common topics and links for quick reference.

#### Conclusions

The Healthy Homes Partnership represents translational research and partnership outputs are functional across diverse audiences, including consumers, healthy homes practitioners, and housing educators. These recently developed smartphone apps can be used in a variety of ways to advance knowledge on unhealthy housing issues and to encourage action steps for families.

#### **[E042] Energy-saving and adjustable water boiler design and experimental research**

Rui Fu, *TMI Episcopal*

Chinese people like to drink boiled and cooled water. On the one hand boiled water is sterilized; on the other hand the hot or warm boiled water can be used to make different drinks such as tea, coffee, or formula milk, etc. However, electronic water boilers have problems such as large energy consumption, non-adjustable outlet water temperature, and the problem of boiled water being mixed with un-boiled water before boiled again, which is undesirable for a water boiler. This paper presents a good solution to achieve the goal of saving energy, making adjustable outlet water temperature, and making the boiled water more healthy.

Through the use of efficient heat exchangers and the use of solenoid valves that control the cold side flow method, the design supplemented a reasonable layout: heating box, heat exchanger, and outlet were approximately distributed from top to bottom. This design achieved the function of continuous output of adjustable temperature boiled water, from forty to a hundred degree celcius. Based on the heat recovery design, around 30%-70% electricity energy could be saved for a whole year operation. The design also fundamentally solve the problem of the mixing of boiled water and cooled water.

The problem at the current stage of the research is that the residual heat and water of the heat exchanger have a certain influence on the output water temperature, which cannot be eliminated for the time being. The next step of our research will be focused on solving this problem.

### **[E043] Simulation study on heat storage characteristics of buried water tank-soil coupling system**

Haotian Huang, Yimin Xiao, *Chongqing University*

Solar seasonal thermal energy storage (SSTES) is an effective way to alleviate energy problems. However, the large storage volume is a major factor limiting its application. In order to use the heat storage capacity of soil, this paper proposed to use buried tank coupled with soil. Taking a building in Taiyuan, Shanxi Province as an example, the long-term operational status and heat storage-release characteristics of SSTES were studied using numerical simulation methods based on hourly load and local hourly weather data. Result shows that after two years of operation, the system tends to be stable. During the heating season, a lot of heat is transferred from soil to tank, which can reach 9% of the annual load. In the case of limited tank volume, solar fraction can be effectively increased in this way.

### **[E045] The Harsh Realities of Poor Quality Rental Housing on Health**

Ms. Maree Young, Jason Matthews, *Taranaki District Health Board*

#### **Aim**

To identify key issues and health impacts of rental housing in Taranaki for families with children aged 0-14years

#### **Methodology**

The information was collected through a mix of quantitative and qualitative research methods; a literature review, secondary analysis of housing data, key informant interviews with providers of emergency housing and property managers of private rentals, and in-depth interviews with families/whānau living in rental properties.

#### **Results**

There is an increased demand for rental housing in Taranaki, with strong competition 'at the bottom end' of the market; i.e. properties below \$350 per week. Property Managers reported that rentals 'at the bottom end of the market' were more likely to be in poorer condition than owner-occupied housing, supporting the findings from the national BRANZ (2015) survey.

Nearly all of the rental participants stated their rentals had mould present larger than an A4 sheet of paper in their house. Three-quarters of rental participants stated their house felt damp. Findings highlight the issue of fuel poverty. The majority of the rental participants struggled to keep their houses warm especially for their children's well-being, with being able to afford to pay their power bill. For some participants, having a cold house resulted in functional over-crowding where all the people in the household slept in one room to keep warm in the winter.

The most common health concern for whānau /families participating was respiratory tract illness, such as asthma exacerbations, chest infections/pneumonia, bronchiolitis and croup. Many of these illnesses were recurring and resulted in many visits to the doctor and/or emergency department, admission to hospital, and time off school or work.

Making insulation mandatory by July 2019 had a positive impact on both the awareness of the importance of insulation and insulation being retro-fitted into rental housing.

#### **Limitations**

Participants were all living in Taranaki recruited through the Taranaki District Health Board Paediatric Service. Key themes from the in-depth interviews were well supported by the literature.

**[E047] Counting snug houses: a quantitative study assessing the long term impact of home insulation on residents health**

Mrs Caroline Fyfe, *Massey University*

A retrospective cohort study follows residents of Warm-Up New Zealand (WUNZ) insulated houses over a six-year period to assess the health effects of home insulation.

Retrofitting insulation reduces the flow of heat from warmer to cooler spaces. In houses heat is lost from living areas through external surfaces such as walls, windows, floors and ceilings. Home insulation can also reduce damp getting into the fabric of the house by potentially increasing indoor temperatures, as warmer air has a lower relative humidity (Goldschmidt, 2014). The Warm Up New Zealand Heat Smart programme, which retrofits insulation, was designed to provide "warm, dry and more energy efficient homes", (EECA, 2016). A cost-benefit analysis of Warm-Up New Zealand attributed 99% of total benefits to improved health, (Grimes, et al., 2012).

Study participants were identified by linking WUNZ address datasets to addresses on primary healthcare (GP) registration records. As primary healthcare records are updated and a new record created every three months, it is possible to follow each person that lived in a Warm-Up New Zealand house for the length of time that they were resident. An encrypted National Health Index (NHI) number attached to each record allowed health information to be collected anonymously.

Linking datasets creates a means of tracking the study population by address, over time, so that long term follow-up can be undertaken. Long term follow-up is important as it allows behaviour around home heating to 'bed in'. For example, initial energy cost savings may be used to heat the house to a more comfortable temperature- termed "take-back", (Howden-Chapman, et al., 2009). In addition events such as infectious disease outbreaks and climatic cycles (such as El Niño and La Niña) can be controlled for. Data linkage also provides a much larger study population than would otherwise be possible.

**[E048] Transition of building materials and associated life cycle environmental performance in rural China**

Dr Wu Deng, Dr Tongyu Zhou, Dr Issac Yu Fat Lun, *University of Nottingham Ningbo China*

From the early 1980s onward, the construction practice in rural China has shown a gradual transformation from using locally available materials such as stone and wood, to urban-like and highly processed modern building materials, e.g. concrete, baked brick and steel. This transition may have a significant impact on the building's environmental performance such as indoor thermal comfort and life cycle energy consumption. This paper examines several types of residential houses in rural China, built in different times. The research indicates that replacing traditional materials with modern ones has not improved the indoor thermal comfort equally with the increase of life cycle energy input. Furthermore, rural houses in China, compared to urban houses, are less thermally comfortable and less energy efficient. Many of them need retrofitting in the near future. Given the

lack of building standards to guide retrofitting rural houses in China, this paper concludes retrofitting practice should be able to address two issues in tandem – increasing indoor thermal comfort and reducing life cycle energy input.

#### **[E051] Study on influence factors of heat storage for PCM walls**

Dr. Wei Wang, Professor Jingchao Xie, Professor Jiaping Liu, *Beijing University of Technology*

Incorporating phase change materials (PCMs) into buildings is an efficient way to increase the thermal storage capacity of the building, thus reduce the energy demand. To improve indoor thermal comfort level and the heating load at night, this paper analysed the influence factors of heat storage for PCM walls in the daytime based on the theoretical and numerical method. Using the heat balance equation of the PCM wall and the indoor air, the coupling relationship among ambient conditions, thermal properties, temperature and heat storage of the PCM wall was obtained. Temperature of the indoor air temperature was decided by the average ambient temperature, temperature rise caused by the indoor heat source, and the temperature fluctuation caused by the dynamic ambient temperature and properties of the wall. Temperature of the PCM wall was higher than the indoor air, because the temperature rise caused by the solar radiant heat through the window and the heat convection on the wall surface was added. The amount of stored heat was decided by the difference of the maximum temperature of the PCM wall and the melting temperature. Heat conductivity and heat capacity had unobvious influence on the heat storage in the limited time. For heat conductivity, if it was enhanced from  $0.25\text{W}/(\text{m}\cdot\text{K})$  to  $0.5\text{W}/(\text{m}\cdot\text{K})$ , stored heat was improved less than 5% in a day. So heat storage in the limited time is mostly influenced by the ambient condition, heat convection condition, and air change condition. To store more heat in the daytime, the melting temperature should be determined by the maximum temperature of the wall and the comfort temperature for human. The latent heat capacity and the area of the wall should be sufficient. The air exchange between indoor and outdoor and the indoor airflow should be reduced in the daytime.

#### **[E053] Indoor environment and fungal exposure in New Zealand homes**

Dr. Peter McDowall, Dr Manfred Plagmann, Vicki White, *BRANZ*

The quality of the indoor environment is largely influenced by occupant behaviour, particularly around heating and ventilation. In this study we monitored temperature, relative humidity, ventilation behaviour and fungal metabolites in 26 homes within the Wellington region over winter 2017. Small wireless sensors were used to continuously monitor the indoor environment in each room while also providing information on the use of windows and internal doors as a means of ventilation. This allowed us to determine if any relationship exists between the indoor environment and occupant driven ventilation.

In addition, semi-structured interviews were conducted with all participants to further explore their home heating and ventilation habits, problems experienced with damp and mould, and health issues that could be exacerbated by poor indoor environmental quality.

Overall, we observed a tendency towards spot heating resulting in variable indoor conditions for different rooms. This was observed in the temperature measurements and commonly reported by occupants in the participant interviews. There was a high tendency to heat the living room, predominantly in the evening only. This behaviour did not transcend to bedrooms. Very few participants reported directly heating their bedrooms, instead relying on heat transfer from the (heated) living space and/or other mechanisms to cope with the cold.

The propensity for mould growth based on relative humidity was found to be generally higher in bedrooms and bathrooms compared to living rooms, which relates to the increased propensity to heat the latter. These findings were supported by measurements of viable and non-viable fungal spores taken from air samples in the bedrooms of each house.

Participants' perceptions of problems of damp and mould in the home and reported habits to address or mitigate these problems varied widely. Furthermore, results suggest occupant perceptions did not always align with the measured data on indoor environmental quality.

#### **[E054] The carbon footprint of New Zealand's built environment - Hotspot or not**

Mr Ben Fisher, Dr Jeff Vickers, Dr Barbara Nebel, *Thinkstep*

The built environment is often quoted as contributing 2-5% to New Zealand's total carbon footprint. However, these figures account for direct energy use only and do not consider the rest of the buildings' life cycle. By taking a life-cycle view, the authors show that the built environment is responsible for 13-20% of New Zealand's total carbon footprint – a share that highlights it as one of the most important areas to reduce greenhouse gas (GHG) emissions at a national level.

The purpose of this presentation is to share the findings of a recent study that calculated the carbon footprint of New Zealand's built environment across its full life-cycle, spanning from production of building materials, through construction, use and maintenance, and ending with demolition and waste treatment. To do this, the authors applied life cycle thinking to reclassify GHG emissions in New Zealand's Greenhouse Gas Inventory into four broad categories: 'built environment', 'nutrition', 'transportation' and 'other'. This reclassification of the carbon footprint of the built environment increased its contribution from 5% to 13% of the national total. By also considering the emissions embodied in international trade, this share increased further to 20%, recognising that New Zealand is a net exporter.

These findings highlight the importance of building material selection when planning and designing sustainable urban areas in New Zealand – an important consideration for decisions which will lock in emissions for the life of the construction.

#### **[E056] Poor Housing Quality and Overcrowding: Estimating the Environmental Burden of Disease in New Zealand**

Dr Lynn Riggs, Professor Michael Baker, Professor Philippa Howden-Chapman, Associate Professor Michael Keall, Associate Professor Nevil Piers, *Motu & University of Otago, Wellington*

**AIM/PROBLEM:** This paper will assess the Environmental Burden of Disease (EBD) related to the home environment (poor quality housing and household crowding) for New Zealand. New Zealand

households, on average, spent 26% of their gross adjusted disposable income on housing in 2017 (the highest in the OECD), yet indicators suggest housing problems are widespread and household crowding is increasing. Dampness, cold, and mould are common in both owner-occupied and rental dwellings, though evidence suggests that rentals are generally in worse condition than owner-occupied properties. As New Zealanders shift towards renting (from approximately one-quarter to more than one-third of the population between 1986 and 2013), more of the population will be exposed to potentially harmful home environments.

Related health problems generally result from three categories of exposures in the home: infectious diseases (e.g., gastroenteritis, pneumonia, tuberculosis); household exposures like mould or lead (e.g., asthma, allergies, lead poisoning); household injury hazards (e.g., broken bones, head injuries, burns).

**Method/Design/Approach:** The EBD from home environments in New Zealand will be estimated using New Zealand housing exposure assessments and exposure-response relationships. This work will be modelled after the World Health Organization's EBD methodology. Housing exposure assessments will be determined via a systematic literature review and data analysis (e.g., 2013 Census, National Minimum Data Set). Exposure-response relationships will be determined by a systematic literature review.

**Results:** Estimates of EBD from housing will be provided for the entire population of New Zealand and broken down by socio-economic status.

**Discussion:** These results will estimate the disease burden that is likely to be preventable through healthier home environments.

**Limitations:** Estimating the burden of disease relies on various model assumptions, including the degree of exposure from the home environment. However, sensitivity analysis will examine the impact of these assumptions on the results.

#### **[E057] A public health approach is critical when developing Environmental Health Indicators for the indoor environment**

Mrs Kylie Mason, Kirstin Lindberg, Associate Professor Deborah Read, Professor Barry Borman, *Massey University*

**Aim:** This project used a public health assessment process to create a set of environmental health indicators (EHIs) to monitor the adverse effects of the indoor environment (eg indoor air pollution, household crowding, damp and mould, and safety hazards) on human health in New Zealand.

**Methods:** A three-stage process of scoping, selection, and design was used to create a set of indoor environment EHIs. Key indoor environmental issues and causal health outcomes were identified and the resulting 24 potential indicators evaluated against a set of indicator selection criteria. The 20 specific health indicators were further assessed against five subcriteria to prioritise their public health impact: number of people affected (based on attributable burden), severity of health impact, whether vulnerable populations were affected and/or large inequalities were apparent, whether the indicator related to multiple environmental exposures, and policy relevance.

**Results:** The eight indoor environment EHIs determined from the three-stage process were: household crowding, second-hand smoke exposure, maternal smoking at two weeks post-natal,

asthma prevalence, asthma hospitalisations, lower respiratory tract infection hospitalisations, meningococcal disease notifications, and sudden unexpected death in infancy (SUDI). Attributable burden indicators were also identified for development.

**Discussion:** The study demonstrated the necessity of including a public health impact assessment in developing and prioritising EHIs for the indoor environment. The process confirmed that housing quality and availability adversely affects the health of New Zealanders, particularly children, Māori and Pacific peoples. Focusing on vulnerable population groups is critical to providing evidence for policy-development to reduce inequalities.

**Limitations:** Indicator selection can be limited by data availability and quality. Further work may also lead to the inclusion of the following EHIs: damp and mouldy housing, once 2018 Census data becomes available; and hospitalisations for injuries occurring in the home, if injury location data is found to be of sufficient quality.

### **[E059] LIVING AROUND TE TĀTUA A RIUKIUTA: Three Kings Volcano, Quarry and Suburb**

Richard Reid, *Richard Reid & Associates Citymakers*

This presentation will outline a design methodology and masterplan proposal for landscape rehabilitation and urban development of Three Kings Quarry, Auckland.

Three Kings Quarry is sited 8km south of the city centre and is 15.1 hectares in area and 25-40 metres in depth. It has been in private operation for over one hundred years and during that time has mined substantial parts of Te Tātua a Riukiuta Three Kings Volcano. Te Tātua a Riukiuta originally comprised five volcanic cones and numerous scoria mounds nested within a large tuff ring. Its sublime landscape has been a formative influence on city planning of the suburb surrounding it.

A whole-systems approach to rehabilitation and development will re-establish the value and presence of the remnant volcanic landscape while planning for a compact, medium-density, mixed-use community around it. Key to achieving this will be raising the quarry floor level to connect it with the neighbourhood; providing significant areas of recreational open space which will also enhance the volcano's spatial setting; stitching together the fragmented street network; and incorporating the redevelopment potential of the adjacent town centre and Housing New Zealand properties into the masterplan.

In a reversal of Auckland's historically abusive relationship to its volcanoes, the design of transportation, buildings and green infrastructure is integrated with the circular structure and radial arrangement of remnant volcanic features. This re-balancing act fulfils the community's objective: "Develop a sense of local character and identity around the presence of Te Tātua a Riukiuta."

The quarry owner's resistance towards an integrated approach to urban design and sustainability means political leadership is required for the masterplan to progress. Given the masterplan encompasses the neighbourhood and better provides for the city's housing shortage, it makes sense for the government to take on the role of horizontal developer.

**[E060] Applicability study of Passive House technology in Hot Summer and Cold Winter zone**

Xinyun Cao, Professor Runming Yao, Associate Professor Wei Yu, *Chongqing University*

As an aggregation approach of energy-saving technologies, there are plenty of energy-saving standards published and applied in different countries. One of the most famous standard, Passive House from Germany has been frequently used all around the world. However, it is arguable of simply applying this German standard to the building design in different climate conditions, especially for the buildings located in the regions with long hot weather time, such as the Hot Summer and Cold Winter (HSCW) zone in China. Some studies have already set a quite uniform standard in this region without considering the climate and human's behavior differences, it is of great significance to discuss the applicability of this German standard in HSCW zone in order to reduce potential over-heating risk and material waste. This paper studied seven typical cities from HSCW zone (Chongqing, Shanghai, Chengdu, Hanzhong, Wuhan, Dongtai and Yinbin), and the heating and cooling demand of these cities were quite different. A typical residential building model was established in this paper and 270 scenarios of each city were simulated by using EnergyPlus software. The balance between economic and energy-saving effectiveness under different scenarios of external envelopes were discussed and evaluated. The results showed that the Passive House standard is only applicable in several cities in HSCW zone where the heat preservation is the main issue in winter, which means that it is not applicable in most cities. Furthermore, this paper provides a set of recommended U-values of external envelopes for each simulated city, which can save up to 20.5% of energy consumption in heating and cooling.

**[E062] Study on Human Adaptive Thermal Comfort Based on Tracking Method—Taking residential buildings in Chongqing for Example**

Miss Ru Ming, Professor Baizhan Li, Associate Professor Wei Yu, *Ministry of Education, Chongqing, China*

Existing research methods of thermal comfort, whether it is based on the heat balance of human body and human thermal adaptability, are mainly carried out by horizontal tests and questionnaire survey, however, seldom consider the dynamic demand of residents as the change of environmental conditions. To solve the problem of the existing thermal comfort evaluation methods ignoring the human adaptive feedback in time division, a field survey was conducted on works' thermal comfort in 20 residential buildings from late spring and early autumn covering the whole cooling period in Chongqing and Hangzhou, China. The tracking method was used in this study, which required that environmental parameters can be collected continuously, and the subjects are fixed, which means they can participate in the questionnaire survey repeatedly. A total of 29 subjects participated in this study, and a total of 827 valid questionnaires were completed by occupants during the survey. The division of time periods was determined by obtaining the evaluation results of outdoor weekly running temperature and indoor thermal environment. It is revealed that the occupants' behaviors exist a large discrepancy in different periods. Human adaptive behaviors in different periods were analyzed, and obtained the reasons of thermal sensation different. It is found that the adaptive behaviors that influenced human adaptability were different in each period, and the occupants mainly adopted different adjustment modes.

### **[E063] Research on the Utilization Potential of Fans in the Yangtze River Basin**

Yue Zhang, Wei Yu, *Chongqing University*

As the rapid development of modern society, people's demand is increasingly higher on the thermal comfort of the indoor environment of buildings. Most of the Yangtze River Basin are hot and wet in summer, people are in urgent need of environmental improvement. However, using air conditioner without regard to conditions will only increase the pressure of energy consumption. In fact, as a low energy consumption product, fans can effectively adjust the thermal comfort of human body and prolong the non-cooling time to have a large space for use in the Yangtze River Basin. In this article, the compensation curves of air velocity to human thermal sensation were obtained by experiments under different temperature and humidity conditions and the energy consumption simulation software EnergyPlus was used to simulate the hourly room temperature of typical residential buildings in cities along the Yangtze River region under natural conditions. Through the analysis of the simulation and experimental results, the range of thermal comfort adjustment that fan can replace air-conditioner is obtained, that is, the non-cooling time can be extended by fan and the energy consumption saved by using fan in corresponding time was calculated. This result fully proves that the fan is a powerful means of thermal comfort regulation in the Yangtze River Basin and also provides theoretical and technical support for energy conservation and emission reduction in this area.

### **[E064] Differences in thermal comfort between elderly and young people in natural ventilation residential buildings in summer**

Miss Ke Yan, Professor Baizhan Li, Professor Hong Liu, Mr Heng Zhang, *Ministry of Education, Chongqing, China*

With the increasing ageing society in China and the improvement of people's living standards, the health and comfort of the living environment of the elderly has received widespread attention. Standards ASHRAE and EN15251 suggest that thermal adaptive models can be used to evaluate and design the basis of the thermal environment of naturally ventilated buildings, but they do not take into account the differences in the ability of the elderly to perceive and adapt to the environmental thermal environment. This paper aims to compare and analyze the differences in comfort temperature range between the elderly and young people in a natural ventilation environment, and propose an indoor environmental regulation strategy for the elderly. The air temperature, humidity, airflow speed and black ball temperature of the naturally ventilated house were tested and the comfort of the indoors was asked. Analysis of the thermal comfort of subjects of different ages shows that the acceptable temperature range for young people is 22.5~28.7 °C, and the acceptable working temperature range for the elderly is 22.6~30.5 °C. Young people have a wide range of acceptable temperatures. At the same time, it has been found that the use of airflow can improve people's thermal sensation. On this basis, a wind speed to temperature and humidity compensation model suitable for the elderly is proposed. Provide reference for the design and optimization of the indoor environment of the aged building in the hot and humid area.

### **[E065] Designing buildings that enhance the quality of life and creating sustainable communities**

Mrs Carolyn Savage, *NZRAB, NZIA*

Purpose: Creating sustainable homes – removing barriers

The importance of housing, the costs of modern technologies and accessibility for all requires new approaches to provide homes that meet the unique demands of the multi-cultural diversity of New Zealand and the Pacific Region.

Design/Methodology/Approach:

Location, orientation, the importance of place, cultural integration/immersion and identity of place, understanding the specific needs of the end users and how the requirements to add a stronger context within existing environments. How the overall design of a building can create an enhancement of wellbeing and sense of place for the end user.

Results:

Design is the collaboration of all parties that achieves an outcome that ensures the dwelling meets the original brief and expectation. A successful result is when a client does not see themselves leaving their new home, but even looks at potential future development opportunities.

Discussions:

What were the outcomes learnt from individual dwellings that are transferable for multi-housing and social housing communities? How can principles implemented for one-off housing be incorporated into large social housing development, without limiting the potential for sustainability and meeting cultural needs for modern developments.

Limitations:

Breaking down the barriers of financial restrictions, creating dialogue and engagement within communities to meet both sustainability and accessibility of new technologies without cost restrictions to best practice and design outcomes. Ensuring homes can operate efficiently without the need of technical IQ.

### **[E070] Detailed measurement of indoor $\gamma$ ray dose rate distribution and directional radiation in detached house in Fukushima**

Associate Professor Hikaru Kobayashi, Shusaku Nakajima, Yusuke Ichijo, Hiroshi Yoshino, *Tohoku University*

The accident of the Fukushima nuclear power plant caused by the tsunami of the 2011 Great East Japan Earthquake widely dispersed artificial radionuclides into the environment, and many residents were forced to evacuate. Right after the disaster occurred, the outdoor gamma ray air dose rate within a wide area, the majority of which was within Fukushima, was at a fairly high level. However, due to subsequent decontamination work, it has since been considerably reduced in many areas. In recent years, evacuation orders have gradually been lifted, and some residents are beginning to return home. Taking this into account, housing reconstruction is underway, but the radiation dose

rate of some sites is still over 0.23  $\mu\text{Sv/h}$  of the Japanese government's decontamination target value. In order to keep occupants' dose rate at a lower level, it is beneficial to clarify the mechanism by which the wooden outer walls of houses can shield against gamma rays, and the typical gamma ray distribution in houses. In turn, this knowledge can be used to improve the shielding performance of houses. In this paper, the measurement results of gamma ray dose rate distribution inside and outside a wooden building in Fukushima, and radiation incidence passing through the outer walls, are reported in detail. Specifically, radiation incidence was measured using a collimator developed by the authors of this paper. Finally, using the directional gamma ray and spectrum measurement results, the shielding performance of the exterior wall of the building is evaluated and discussed.

**[E072] Accuracy Check on Estimation Method for Energy Consumption of Domestic Refrigerator by Using Actual Measurement Data**

Mr. Kosuke Maeda, Mr Kotaro Kawata, Dr Masaki Tajima, *Kochi University of Technology*

The energy consumption of consumer electronics accounts for approximately one-third of the total home energy consumption in Japan. Domestic refrigerators are generally used continuously, therefore their power consumption become relatively large. It is important to grasp the power consumption of the refrigerators under actual conditions because the actual power consumption is often different from the specification value measured by using Japanese Industrial Standards (JIS) C 9801. It is also necessary to verify the energy estimation method using surrounding temperatures which immediately affects the power consumption.

In this study, the accuracy of an estimation formula for refrigerator's power consumption proposed by the LEHVE project is checked by comparing the estimated value to the measured value which is obtained with multiple measurement intervals. With respect to the power consumption of the defrosting operation in the estimation, the length of the time is investigated. As a result, in case of the daily defrosting time as 2 hours, the estimated power consumption results most precise. The daily power consumption using 10 minutes measurement data can also grant estimation accuracy.

Finally, the estimation accuracy is checked by comparing the estimated value with additional 10 minutes measured value of refrigerators employed in typical households.

**[E074] The impact of material change of urban underlying surface on surface heat transfer: a case study of Chongqing University City**

Hongjie Zhang, Qing Luo, *Ministry of Education, Chongqing*

As of the end of 2017, China's urbanisation rate reached 58.52%, and urbanisation led to dramatic changes in the material of the underlying surface. The reduction of natural underlay materials such as green spaces and water bodies, and the increase of artificial materials such as asphalts and cements have changed the form of urban surface heat flow, causing urban heat accumulation and deteriorating urban thermal environment. Through satellite image analysis and field investigation, this paper analyses the proportion change of six typical underlying surfaces of vegetation, soil, water, concrete, asphalt and rubber from 2005 to 2015, and calculates the heat transfer of different

underlying surfaces and air. The results show that after 10 years of urbanisation, the total proportion of vegetation, water and soil has been reduced by 26%, and all of them have been replaced by artificial materials, resulting in an average annual heat flux of the urban underlying surface and air increased by 1.496w/m<sup>2</sup>. The average increase rate was 0.37%, and the summer increase rate was 0.65%. The increase in infrared radiation energy caused by the material change of the underlying surface is the main reason for the increase in heat flux density.

**[E075] Influence of room aspect ratio on the purification effectiveness of air purifier**

Mr. Kaixuan Wang, Professor Runming Yao, Dr Han Wang, *Chongqing University*

With the emergence of the wide range of fog and haze in China, indoor air pollution and governance has attached widespread concerns, which have a serious impact on people's health. Currently, apart from air conditioning system, air purifier is considered as an effective device to improve indoor air quality (IAQ) and to clean indoor pollutant (e.g. carbon dioxide, formaldehyde and fine particulate matter). Not the structure characteristics of air purifier, but the environmental condition including the location and room shape, may have a great influence on the purification effectiveness. However, the influence of room aspect ratio such as length-width (L/W) ratio and height-width ratio (H/W) are ignored in the previous studies. In the paper, numerical simulation by computational fluid dynamics (CFD) and experiments were implemented to investigate the impact of room aspect ratio. The CH<sub>2</sub>O concentration and the concentration uniformity index in respiratory region were analyzed and discussed. The results showed that the environmental condition had a significant impact on the purification effectiveness, and there was the optimal value of L/W and H/W corresponding to the lowest CH<sub>2</sub>O concentration in respiratory region. Furthermore, the best location of the air purifier can be confirmed by the CH<sub>2</sub>O concentration and the concentration uniformity index. The results of the study are expected to provide references for the air purifier layout and quantity selected of the air purifier.

**[E080] Are New Zealand Tenants Still Fuel Poor? A study on the awareness and effects of fuel poverty in low-income households**

Dr Eziaku Onyeizu Rasheed, Mr Luke Holliday, Mr Nitesh Mohanty, *Massey University*

This study aimed to ascertain whether New Zealand tenants are still fuel poor. To achieve this, two objectives were set: (a) to investigate the level of awareness of tenants to fuel poverty and (b) to ascertain whether fuel poverty is evident in the households of low-income tenants. A two-stage survey was carried out on tenants in low-income households within Auckland city. Firstly, an online survey targeting 50 tenants across Auckland city was undertaken to establish the awareness of tenants on fuel poverty. Secondly, a field survey was carried out on 50 rented households using a paper-based questionnaire and pictorial observation of the evidence of fuel poverty. The results showed that there is still significant lack of awareness of fuel poverty amongst the tenants. In addition, the majority do not seek advice on fuel poverty and the associated effects. This study concludes that fuel poverty is still prevalent in rented households despite government's effort to deal with it. This study calls for more efforts to be made by the appropriate authorities to inform the public, in particular, those affected, about fuel poverty in the country. The responsible authorities should do more to eradicate fuel poverty in the country. This study was carried out on a small

population of low-income earners. More studies are required across the country if the results are to be generalised.

**[E081] Liveable in Auckland City – An insight into the prospect of Mixed-Use Developments**

Dr Eziaku Onyeizu Rasheed, Mr Richard Callister, Mr Jun Bai William Huo, Dr Temitope Egbelakin, *Massey University*

With Auckland’s population projected to increase by 2.2 million people by 2043, the demand for urban growth management is imperative. Research indicates that the aims of densification align well with urban growth management strategies and suggest that it may be beneficial to invest in mixed-use developments in the high-density cities. However, a recent study has shown that there is still resistance to high density living amongst occupiers of Auckland City. The aim of this study was to understand the perception of occupiers and investors on liveability in Auckland city to the extent that stakeholders are prepared to invest in mixed use developments as a support to high quality densification. While the results showed a consensus on potential benefits to the city and neighbouring cities, there were interesting findings on liveability that will significantly impact on quality of life amongst occupiers and the readiness of stakeholders to invest in mixed-use developments in Auckland city. This study provides significant insights on the prospects of mixed-use development as an urban development strategy to meet the present and future development needs of Auckland city.

**[E082] Social Sustainability: the neglected dimension of neighbourhood design and development**

Tricia Austin, Farzad Zamani, Roja Tafaraji, Kareem Ismail, Jacquelyn Collins, Kate Scanlen, Polly Smith, *University of Auckland*

Down-playing the importance of social sustainability in neighbourhood design, can negatively impact on the quality of life led by residents; reduce the potential for communities to evolve and become resilient; and will do nothing to reduce our future carbon emissions. We know that the design of new residential developments can facilitate social interaction; can make it easier for children to play independently and safely outside of their homes; can produce the next generation of pedestrians and cyclists; can enable older people to age in place; and can ensure that people with a disability are able to fully access their surrounding neighbourhoods. Once construction is complete, it is costly (if not impossible) to retrofit the structures of neighbourhoods - that is the streets, the public spaces and parks and the public-private spaces, such as the communal shared driveways. It is important that masterplanners, urban designers and property developers have a clearer understanding of how the spaces around a dwelling are used, and that their plans and designs are more resilient to changing demographics over the lifetime of the development.

This paper describes a study of several neighbourhoods within a master-planned residential development under construction on a former NZ Airforce Base, in Auckland, known as Hobsonville Point. The research includes a survey of local residents; observational data of the use of external spaces; a mapping analysis; and an accessibility assessment. The neighbourhoods are compared with each other, and then the findings contrasted with those from a similar analysis undertaken in

England. The research findings highlight the importance of actively acknowledging social sustainability at the outset of the planning and design process; and the need to ensure that the design of open spaces, streets, and pedestrian networks positively contributes to the residents' lives.

**[E088] Dynamic control strategy of air conditioning based on human thermal sensation and energy saving**

Shangyan Wu, Professor Baizhan Li, Professor Wei Yu, Professor Runming Yao, *Chongqing University*

In order to find the control strategy of air conditioning based on human thermal sensation and energy saving, the experimental scheme is designed from two perspectives of time and space. The investigator have been monitoring the temperature and humidity of usual airflow organizations form of different types of building in Chongqing. Meanwhile, the wind speed was also be measured. And the test space was mainly human activity area which height is lower than 1.8m in the test room. At the same time, the sensation voting questionnaire was distributed to the mobile people in the test room. The questionnaire mainly votes on the three senses of thermal sensation, wet sensation and wind sensation. Meanwhile, the clothing types of the surveyors in the test room are filled in. The relationship between setup parameters and actual parameters of the air is found in the test data. And the law of transition from one stage to another can be discovered when the setup temperature or wind speed change. In addition, based on the results of test and thermal sensation voting, this paper has developed a dynamic air conditioning control strategy, which is to meet both the human thermal comfort from two angles of time and space and energy saving needs. To some degree, this paper finds some theoretical basis of air conditioning strategy based on both the of human body thermal comfort and the energy saving of air conditioning.

**[E091] Analysis of pollution characteristics and influence factors of PM<sub>2.5</sub> in an university student apartment in Chongqing**

Mr Du Chaojun, Mr Zheng Jie, *Chongqing University*

From November 2015 to February 2016, field tests were conducted on indoor and outdoor PM<sub>2.5</sub> concentrations at a university student apartment in Shapingba District of Chongqing. The results showed that the diurnal variations of indoor and outdoor PM<sub>2.5</sub> concentrations areas for all daily average is consistent. The peak values are normally observed at 09:00 (75 mg/m<sup>3</sup> and 110 mg/m<sup>3</sup> for indoor and outdoor, respectively) and the lowest values are normally observed at 13:00 (50 mg/m<sup>3</sup> and 80 mg/m<sup>3</sup> for indoor and outdoor, respectively). The delay time of the outdoor PM<sub>2.5</sub> transmission to the indoor is 54min. The outdoor air temperature was negatively correlated with indoor and outdoor PM<sub>2.5</sub> concentrations, and had no significant correlation with the I/O ratio. The outdoor relative humidity was positively correlated with the indoor and outdoor PM<sub>2.5</sub> concentrations, and was negatively correlated with the I/O ratio. The outdoor wind speed was negatively correlated with indoor and outdoor PM<sub>2.5</sub> concentrations, and was positively correlated with I/O ratio. The research results can provide scientific support for the subsequent establishment of indoor PM<sub>2.5</sub> concentration prediction model for university student apartments.

**[E094] Mixed tenure communities in New Zealand: drivers and challenges, benefits and concerns**

Dr Elinor Chisholm, Professor Philippa Howden-Chapman, *University of Otago, Wellington*

Building mixed tenure communities, including on land previously occupied primarily by state housing, has been presented as a way of dealing with some of the challenges associated with deprived neighbourhoods, while also increasing market housing supply. However, concerns have also been raised that depending on their implementation, mixed tenure communities will not see out expected benefits to wellbeing for social tenants.

Redevelopment of public housing into mixed-tenure communities is a well-established practice in a number of countries. In 2018, when a number of projects have been recently completed or are being initiated, it is timely to consider how the idea of mixed-tenure communities has been adopted in the New Zealand context.

This paper presents findings from a project involving 32 interviews with developers, policy thinkers, politicians, housing providers, and urban designers that are involved in establishing mixed tenure communities in New Zealand. It looks at definitions for mixed-tenure communities, and key design features, suggesting that the concept of mixed-tenure means different things to different people. The paper outlines key drivers for building mixed-tenure communities, and challenges that housing providers and developers have encountered in this process. Participants share their thoughts on benefits for residents living in mixed tenure communities, as well as some concerns.

**[E098] Housing quality, home safety, rental housing, environmental health, housing assessment**

Dr Lucy Telfar Barnard, Dr Julie Bennett, *University of Otago, Wellington*

As in many other countries, rental housing in New Zealand is in worse condition than houses that are owner-occupied. After original construction signoff, New Zealand has no inspection regimes for residential buildings and laws and regulations mandating standards for existing residential housing are outdated and spread over a range of instruments. Policies to improve standards in existing housing have been notoriously difficult to implement. This presentation describes the development and implementation of a rental Warrant of Fitness (WoF) intended to improve occupants' health and reduce injuries through housing quality improvements. The WoF is based on two decades of research on the impact of housing quality on New Zealanders' health and wellbeing and is strongly influenced by the UK Housing Health and Safety Rating System. To pass the WoF dwellings must pass each of 29 criteria for habitability, insulation, heating, ventilation, safety, amenities, and basic structural soundness. This paper presents details of the WoF's development, including field testing; and implementation, in which we worked with a city-level local government council.

### **[E099] An holistic conceptualisation of LGBTIQ+ homelessness**

Miss Brodie Fraser, Dr Hera Cook, Associate Professor Nevil Pierser, Dr Elinor Chisholm, *University of Otago, Wellington*

Lesbian, Gay, Bisexual, Transgender, Intersex, and Queer (LGBTIQ+) people's experiences of homelessness is an under-explored area of housing and homelessness studies, despite this group making up 20-40% of homeless populations. A review of the literature indicates that LGBTIQ+ identifying people who are homeless experience much greater levels of wellbeing issues (such as poor mental and physical health, substance use, HIV, and sexual abuse) than their non-LGBTIQ+ homeless counterparts. Despite this, the existing literature on LGBTIQ+ homelessness does not take an holistic view of the relationships between these key issues, instead placing them into individual siloes.

**Aim:** The aim of this literature review was to expand upon existing reviews of the topic and make clear the interconnected relationships between key themes in the literature.

**Methods:** This review used two reviews from Ecker (2016, 2017) as its foundation. Five database searches were run; "LGBT Housing First;" "Queer Housing First;" "Sexuality Housing First;" "LGBT Homelessness;" and "Queer Homelessness."

**Results:** Levels of LGBTIQ+ homelessness have increased by an average of over 10% between 1991 and 2017. The key themes that arose in the literature were; poverty, family, foster care, discrimination and stigma, shelter inaccessibility, HIV, sexual abuse, survival sex and sex work, substance use, mental health, physical health and victimisation, and ethnicity.

**Conclusion:** People who identify as LGBTIQ+ experience homelessness at far greater levels than their non-LGBTIQ+ counterparts, and are more likely to experience a host of mostly negative factors. This review indicates a strong need to view this issues holistically, instead of in siloes.

### **[E100] Does paying people to keep warm at home work?**

Helen Viggers, Associate Professor Michael Keall, Dr Kristin Wickens, Professor Philippa Howden-Chapman, *University of Otago, Wellington*

The cultural purpose of energy is to provide useful services that increase the utility of people's lives. Although it is necessary to use energy prudently in order to reduce climate change, it is also necessary to use energy to maintain or improve wellbeing. People spend about 90% of their time indoors, and this figure may be even greater for the most vulnerable groups of the very young and the very old. Many homes in New Zealand are cold. People spending long amounts of time in cold homes can have problematic health consequences, especially if the inhabitants are vulnerable.

The Warm Homes for Elder New Zealanders Study credited the electricity accounts of older people who had Chronic Obstructive Pulmonary Disease with an additional \$500 during one winter, and observed the outcomes in terms of household electricity use, indoor temperatures and health consequences.

This paper reports on the effect of this supplementary payment on the electricity use in the households over winter, and the indoor temperatures experienced.

**[E102] Research on axial flow velocity of circular smoke vents in high-rise buildings**

Hou Qiankun, Miao-cheng Weng, *Chongqing University*

In high-rise buildings, if a fire occurs in the building it is one of the most serious potential dangers, it may be very difficult for staff to evacuate within the toxic fire smoke in high-rise. So it is especially important to remove the smoke in time. Induced velocity is the main factor for smoke extraction, the areas of outlet play a major role in induced velocity, some researchers have got conclusion about airflow velocity for rectangle. As for circular smoke vent, need a deeper study. Fluent is used to simulate the velocity of outlet. A small-scale model verified the conclusion. Due to the simplification of the model, the conclusions and simulations have some errors, and these are feasible.

**[E103] Analysis on Effect of Photovoltaic External Sunshade in Chongqing to Indoor Opto-thermal Environment**

Zuo Wu, Professor Yong Ding, *Chongqing University*

In the southern hot areas of China, the temperature is high and lasts long in summer, the solar radiation is strong, as well as the solar radiation accessing to the rooms through the external windows can bring several problems e.g. poor indoor hot environment, serious glare etc. However, the sufficient solar radiation also provide great potential to the application of solar photovoltaic technology. The photovoltaic external sunshade device improves the indoor opto-thermal environment on one hand, which on the other hand applies the sufficient solar energy resource in summer to generate power for meeting the need of indoor lighting and night lighting. Therefore, this paper takes Chongqing for example, develops and applies the photovoltaic external sunshade device in one office building of Chongqing, as well as perform the simulation calculation and testing for the indoor lighting, temperatures, indoor solar radiation, photovoltaic power generation under different external sunshade forms and angles. Through analyzing the improvement effect of photovoltaic external sunshade device to the indoor opto-thermal environment and the lighting power generation effect provided by the photovoltaic power generation, verifying the applicability of photovoltaic external sunshade device in this area, so as to conclude the photovoltaic adjustable external sunshade design and adjustment strategy that are applicable to the hot summer areas.

**[E104] Experimental study of the heat recovery system with on the flue gas-air total heat exchange**

Professor Fu lin, Professor Zhao Xiling, *Tsinghua University*

District heating is an essential part of modern life but consumes a great deal of energy at the same time. In China, gas boilers are one kind of primary heat sources for district heating, and there is severe heat loss due to flue gas flowing out at a high temperature level. The waste heat recovery of the flue gas of the residential boiler can improve the energy efficiency of the heating system effectively. In the paper, a heat recovery system with the flue gas-air total heat exchange method was proposed. There were three towers and one heat exchanger in the system. Two towers are set to do the total heat exchange process. In tower one, the inlet air of the boiler heated and humidified by the intermediate water, and the intermediate water exchanged the heat and humidity with the flue gas in tower two. The dew point of the outlet of the flue gas is higher than the ordinary system,

which has not the two towers. In tower three, the intermediate cold water sprayed to the flue gas and heated. A flue gas-water heat exchanger used to recover the heat of the intermediate water and sent the heat to the heating system. The heat recovery system has been set up in a gas boiler, which has 2 tons. According to the experiment results, the outlet temperature of the flue gas reduced from 80°C to 30°C, and the recovered heat was about 127 kW. The system also can reduce the pollutant concentration. The exhaust NO<sub>x</sub> decreased from 33ppm to 24.6ppm, the reduction was about 25.4%. The system achieves energy saving and emission reduction simultaneously.

This paper has established a mathematical model for the system and validated the model with experimental data, and the overall performance evaluation of the system were conducted, including energy consumption, environmental and economic feasibility.

### **[E105] Research and Analysis (R&A) on Layout of Indoor Temperature Monitoring Points in Cabinet Air-conditioned Rooms**

Zhenqian Yuan, Professor Yong Ding, *Chongqing University*

At present, the temperature control of the room adopts monitoring of monitoring points to carry on feedback regulation, so the accuracy of monitoring of monitoring points is the key to guarantee the room temperature control accuracy. In the control of current cabinet air conditioner, the monitoring points are generally located in the air return. Due to the restrictions on the location of monitoring points, the monitored temperature will frequently be influenced by the air supply angle, room furniture layout and other factors.

In this paper, the reasonable location of layout of the monitoring points carries out the study to find the suitable distribution location in the room, so as to guarantee that the monitoring values can relatively accurately reflect the state of the indoor environment. First of all, the room is tested according to the detection requirement node placement method, and the detection value is obtained, which is set as the accurate value of the room status; The distribution of indoor thermal environment is obtained by simulation analysis. By analyzing the distribution law of indoor thermal environment relative to the detection values, so as to the distribution of monitoring points which can reflect the indoor design condition is obtained, which provides the shoring of foundation for reasonably determining the monitoring points and ensuring the realization of the control requirements.

The results display that for different indoor environment layouts, there are candidate monitoring points in the thermal environment, moreover, the monitoring temperature has a highly linear correlation with the indoor temperature, the correlation coefficient “R<sup>2</sup>” value can reach more than 0.90, which is superior to the temperature monitoring point at the return air outlet.

This article only carries on the study of cabinet air-conditioned rooms, the research achievements are not necessarily applicable to other air conditioning forms, more forms of air-conditioning air supply condition will be carried on the study using this method in the later stage, so as to obtain principles and correction methods of layout of the monitoring point under different forms of air conditioning.

### **[E108] Night ventilation control strategies in residential buildings**

Miss Qiulei Zhang , Professor Runming Yao , *Chongqing University*

With the rapid development of urbanization, the problem of insufficient global energy supply has become more and more prominent. How to use passive method to create liveable, ecological and energy-saving buildings with low energy consumption has become a common research topic all over the world. Night ventilation appears to be one of the most promising passive cooling techniques, which not only can reduce summer cooling load but also can improve indoor thermal comfort.

Firstly, these present paper aims at analysing the night ventilation potential combined with different climate condition of hot summer and cold winter zone in China. Secondly, based on the intermittent operation behaviour of HVAC systems in the region, investigate the variations that the night ventilation control strategy might undergo when climate condition, building mass, air change rate, and ventilation duration changes.

In order to fulfil these tasks, the summer outdoor climate data of three locations (Shanghai, Wuhan and Chongqing) was analysed and the simulation software Energy Plus was used to simulate the indoor thermal environment and energy consumption in typical residential building under different conditions. As a result, the temperature difference ratio and cooling energy consumption are calculated to have a better understanding and evaluation of the comfort and energy contribution of night cooling techniques.

### **[E110] The PM2.5 Filtration Performance and Comprehensive Assessment of Air Filter Used in Primary Air Unit**

Miss Yan Li, Associate Professor Wei Yu, Professor Runming Yao, *Chongqing University*

As the development of industry, air pollution is becoming more and more serious. The particulate suspends in the air not only affects the visibility, but also will cause harm to human body health. Although PM2.5 is only a small part of the outdoor atmosphere, its small particle size often carries a large amount of toxic substances and can stay in the atmosphere for a long time, continuously affecting air quality and human health. In order to control PM2.5 from the source and effectively reduce the indoor PM2.5 concentration, this research studied the PM2.5 filtration performance of different grades of filters. According to the status quo of PM2.5 pollution in different regions, the applicable filter combination scheme is proposed and its performance is comprehensively evaluated to provide reference and reference for the design and selection of new wind turbines.

In this research, the mechanism and characteristics of air filters are elaborated firstly, and the influencing factors are analysed. Then, according to the requirements of relevant domestic and international standards, the filter performance test bench of the new wind turbine unit was designed and built. Using the test bench, the filtration efficiency and resistance value of PM2.5 of different grade filters were tested, and the resistance curve of air volume was drawn. Then according to the results of single filter experiment, combination schemes are designed and tested. Three-stage filtration can be considered when two-stage filtration cannot meet the control requirement. On the foundation of this, the relative lifetime of different filters in the units are calculated. At last, considering various PM2.5 pollution situation in different, a specific example is given. Different schemes should be assessed considering efficiency, resistance, lifetime and cost in practical applications, and the best option is determined ultimately.

**[E114] Lessons Learned from Implementing a Programme of Home Modifications to Prevent Falls amongst the General Population**

Assoc Prof Michael Keall, Professor Philippa Howden-Chapman, Associate Professor Nevil Pierse, Professor Chris Cunningham, Professor Michael Baker, *University of Otago, Wellington*

Problem: Home fall injuries amongst the general population are common and costly. In the Home Injury Prevention Intervention (HIPI) trial, it was shown that 26% of medically treated home fall injuries could be prevented by a package of home modifications undertaken by qualified builders. This presentation describes how unexpected safety issues associated with the implementation of the programme were addressed.

Method: Following the intervention, participants could contact the builders. Any problems or issues over a two-year period were monitored. Public meetings were held to explain the results of the study and record participants' comments about the trial.

Results: Generally people were satisfied with the modifications. However, there were clear safety issues with particular modifications and builders revisited homes to address these.

Discussion: These findings highlight the need to allocate some resources for monitoring and remediation work to follow up interventions, and also a need for some regulation of the quality of safety products.

**[E115] Analysis of a domestic solar PV and battery storage system in “sunny” Palmerston North**

Professor Ralph Sims, *Massey University*

A 1.5 kW solar PV system and 1.2 kWh battery was installed on a domestic property in Palmerston North in January 2017. The house is grid-connected and surplus power sold to Trust Power. Detailed monitoring of the system every 15 minutes has enabled a close analysis to be undertaken and the cost-effectiveness to be determined. Palmerston North is not the sunniest place in New Zealand yet a reasonable payback period has been achieved for the panels and system based on 1 year of data. However the payback period for the battery is close to 40 years, by which time the residents will more than likely be deceased!

The paper will provide tips on maximising the return on a solar PV investment based on real-world experience.

**[E116] The outdoor housing environment matters too: the role of urban green space**

Dr Paul Blaschke, *Blaschke & Rutherford*

The spaces around houses, including public and private green and open spaces, are very important for residents' health and wellbeing, as well as for the availability of a wide range of ecosystem

services in the urban environment. We have conducted a detailed analysis of green and open space supply and demand in central Wellington City, focussing on accessible public green space (GS). The population of this area is predicted to grow by up to 95% in the period 2013-43. The supply of accessible GS to the current population is already inequitably distributed between the three census area units (CAUs) comprising the central city, and these inequities will increase as the CAU populations grow at different rates. The environmental characteristics and quality of the GS in the three CAUs also differ significantly, affecting the ability of the GS to deliver ecosystem service and wellbeing benefits. GS provision is often seen as competing for scarce land with other fundamental community requirements such as housing, transport connections and stormwater control, but with good policy and design measures can to a large extent complement, not compete, with these functions. Indeed GS should be seen as vital “green infrastructure” and an integral part of functioning urban systems. We present options for improving the supply and quality of urban GS over central Wellington over the next 30 years.

### **[E117] Design Considerations for a Community-Based Smart Electricity Microgrid**

Professor Mark Apperley, Mr Nathan Kelly, *University of Waikato*

This paper describes the technical design considerations for a smart community-based renewable electricity microgrid. Although the motivation for such systems is often focused on cost savings and “feel good” factors, their provision cannot be seen in isolation, but as a part of the larger network or grid, and effectively contributing to a more sustainable environment. The electricity supply industry world-wide has been characterised for the past 100 years by national and international grids, operated with the goal of balancing *power* generation with demand, centrally, in real-time. The industry has become very skilled and adept at managing this situation, and it is this which has determined the complexities, the risks, and the costs, of present day power systems. However, a combination of new renewable energy sources, such as solar and wind, rapidly developing storage technology, and smart control, enables effective and tolerable distributed load matching. Such distributed systems challenge the traditional central grid model, by on the one hand being relatively independent, yet on the other relying on the grid for consumption of excess power, and provision of shortfall. However, smart microgrids have the potential to lead to an entirely fresh approach to overall infrastructure planning, through a bottom-up technique based on localised energy balance, maximising the balance between local generation and local load, and minimising the dependence and impact on the remote resources of the grid.

The Net Zero Energy Balance concept is explored and extended, and a computer-based tool enabling its effective application in a smart, grid-connected, microgrid described. This is then applied to the design of a smart microgrid for a local marae-based community system.

### **[E118] Determinants of observed dampness and measured moisture in the New Zealand House Condition Survey 2004-2015**

Phoebe Taptiklis, Professor Robyn Phipps, Professor Jeroen Douwes, Dr Mark Jones, *Massey University*

House maintenance may be under-valued in terms of its importance to indoor dampness and mould. The BRANZ House Condition Survey is a rich New Zealand housing data source which includes detailed information on house characteristics and condition.

Here it is used to examine the determinants of subjective (inspector rated) dampness, visible mould, musty odour and measured moisture in 3 surveys (conducted in 2004, 2010 and 2015) comprising a total of 1616 houses. Univariate and multivariate analyses were undertaken using dampness measures as outcomes and testing aspects of the houses' condition and characteristics. Such characteristics include cladding materials, presence of insulation and heating and ventilation characteristics. The analysis also adjusted for important confounders including, tenure (rented/owned), occupancy rate, season of assessment and locality.

Maintenance factors, including poor condition windows, claddings and paint on the exterior are predictive of subjective damp, mould and musty odour and to a lesser extent measured moisture after adjusting for confounding factors. This information is of value to both homeowners and regulators and deserves attention.

Limitations of this study include relatively small sample sizes and a lack of information on human behaviours in the context of the house.

#### **[E119] A Theoretical Framework of Community Resilience**

Mrs Graciela Rivera-Munoz, *University of Otago, Wellington*

This qualitative study asks the question of what is community resilience and how can we interpret this common and abstract concept critically. Indeed, much emphasis is placed on promoting 'resilient' communities. However, when planning for an acute shock (like the Canterbury earthquakes of 2010-2011) or addressing long-term or chronic urban stresses (like climate change and social deprivation), the theories and evidence we use to construe what we do have an important impact on the way we structure our strategic responses. Asking this research question required me to engage in a deductive approach to scientific reasoning and theory construction: an analysis of existing evidence and theory to develop a new theoretical framework as a proposition or hypothesis to be further refined and tested empirically. Based on this approach, the study conducted a qualitative systematic review to specify the range of phenomena that the theory addressed; identified the major concepts and variables in the framework and what is known about the relationship among those variables; reasoned logically from those propositions through a case study of the Canterbury earthquakes.

#### **[E120] Wellbeing and social housing: using linked survey and administrative data to evaluate the impact of social housing on people's lives to inform policy**

Mr Conal Smith, Simon Anastasiadis, *Victoria University of Wellington*

Evidence based policy requires government to be able to identify the impact of interventions. Without robust evaluation of the impacts of interventions on recipients' wellbeing it is difficult to know if interventions are actually making a difference in people's lives. This paper examines how

wellbeing outcomes change before and after placement in social housing. It uses a novel approach that combines longitudinal administrative data with a cross-sectional survey data to quantify the impact of social housing on life satisfaction, housing quality, feelings of safety, employment, social connectedness, material deprivation, civic engagement, ability to express culture, and physical and mental health.

Information from Housing New Zealand – the primary state provider of social housing in New Zealand – is used to identify a cohort that both applied for and received social housing. This cohort is linked to four waves of the New Zealand General Social Survey, which provides information across a wide range of different wellbeing outcomes. Variation in when the respondent applied for social housing and when they were interviewed means that some of the sample interviews occur before they are placed in social housing, while some are interviewed afterwards. This allows us to observe a wide range of wellbeing outcomes before and after placement in social housing, while the fact that all respondents are drawn from the same cohort that both applied for and received social housing over the same period controls for selection bias associated with receipt of social housing.

**[E121] He Tipu Manahau: Kia Mau Te Rā (To grow resilience: to keep hold of the sun)**

Ms Cheryl Davies, Professor Philippa Howden-Chapman, *Wainuiomata Marae Trust & University of Otago, Wellington*

This marae-based papakāinga housing project is in Wainuiomata, a vibrant community on the outskirts of the Hutt Valley in Wellington. Wainuiomata marae was established as an urban authority in 1983 and is surrounded by 3.5 hectares of marae reserve land. Wainuiomata marae and our research partners He Kainga Oranga/Housing and Health Research Programme are committed to a housing development of 36 high quality, affordable dwellings on the marae reserve. The plans are for a proportion of the houses will be rented by Housing NZ to local people on the MSD social housing waiting list and the remaining houses will be rented to low-income families, who will join a shared equity scheme. The households will benefit from amenities, such as the existing marae, kohanga reo, communal gardens and a comprehensive range of wrap around health and social services. The marae community has come to an agreement that this co-housing will be open to those who are committed to the marae kaupapa, whether they are Māori, Pasifika or Pākehā. The plans are for the marae and the 36 houses to be powered by a renewable energy-based smart energy micro-grid, developed by energy sector partners Transpower, Meridian Energy and Wellington Electricity, which links the marae with the 30 medium density dwellings.

This project will address the urgent problem in New Zealand of energy security and fuel poverty in residential dwellings. The marae is the prime centre of cultural and social activity and the roof will be fitted with photovoltaic (PV) arrays, to provide the central hub of an energy supply system linked progressively to the surrounding houses as they are built. This project will be an innovative example of a smart energy micro-grid on the grid edge and be a unique test bed for linking energy networks and the new housing developments. Apprenticeships for local youths in installing solar PV and building construction will be another key outcome.

In the medium- to long-term, the plans are that Wainuiomata Marae will be the centre of an urban regeneration laboratory. This carefully documented project will provide benefits for the community and enable us to generate new knowledge for similar communities nationally and internationally.

The plans are that through a community-led process, Housing NZ, along with community stakeholders, university research groups, government agencies and businesses can collaborate successfully on a staged plan to regenerate a marae-based suburban community to realise a range of shared community benefits, as well as private benefits.

**[E124] Actual performance of room air cleaner in odor substance removal ability**

Prof ATSUO NOZAKI, *Tohoku Bunka Gakuen University*

Currently, in order to clarify the odorous substance removal performance of room air cleaners that are on sale in Japan, test evaluation using a large chamber was carried out. The test substances are ammonia, methyl mercaptan, acetic acid, isovaleric acid, indole, toluene and acetaldehyde. In the test, a certain amount of these odor substances were supplied into a large chamber where ventilation rate, temperature and relative humidity were controlled, and the change with time in the concentration in the chamber associated with the operation of the air cleaner was obtained.

In addition, the CADR on each odor substance was determined from the changed concentration of each odor substance in a large chamber. Recently, HEPA filter is installed in most air cleaners, and the CADR according to air cleaner' air volume is recognized.

As a result of the experiment, the following findings were obtained. Comparing the particulate matters, the CADR of each odor substance is very small.

For example, the maximum value of CADR of ammonia is 140 m<sup>3</sup>/h, the second largest value is 110 m<sup>3</sup>/h, and other five air cleaners are in the range of 72 to 6.8 m<sup>3</sup>/h, Almost, it is regarded that there is no indoor concentration reduction removal effect.

In particular, the maximum value of acetaldehyde CADR is 30 m<sup>3</sup>/h, the second largest value is 19 m<sup>3</sup>/h, and the other five air cleaners are in the range of 2.7 to 6.2 m<sup>3</sup>/h, which is considered to have almost no indoor concentration reduction effect.

The air cleaner technology to solve this problem is so called "Mist wash", and the performance clearly increased by operation of the "Mist wash".

**[E126] The Construction of Housing Tenure: Moments of Evolution in New Zealand's Tenure Regime**

Mr Daniel Ryland, *Massey University*

The presentation is from early stages of research seeking to understand the evolution and social construction of New Zealand's housing tenure - so any feedback is particularly helpful! Popular and political discussions of housing tenure commonly focus on a binary of homeownership and renting, defined in terms of legal or Census categories. However, tenure defined in this way does not capture the full breadth of tenure forms within and outside of homeownership or renting, nor does

it adequately capture the relations between people, things, and events involved in tenure. Instead, each time and place have their own unique conceptualisation of tenure and how it manifests. Neglecting the factors from context artificially restricts tenure options available to households, and limits potential improvements for individual and neighbourhood wellbeing.

A historical perspective will be used to explore the evolution of New Zealand's housing tenure by looking at significant moments when understandings or practical applications changed. These will be contextualised for their role in shaping understandings of tenure, particularly their influence in altering and creating tenure forms beyond the homeownership and renting binary. As knowing the inertias and elements contributing to shaping tenure will contribute to improving the finding and adapting tools best suited to provide additional options and opportunities going into the future.

### **[E127] Te Ara Mua-Future Streets: participatory street re-design at a neighbourhood scale**

Professor Karen Witten, Dr Hamish Mackie, Associate Professor Melody Smith, *Massey University*

**Aim/Problem:** Transport planning has prioritised efficient car travel over other modes in New Zealand's suburban neighbourhoods, diminishing neighbourhood sustainability through declines in active travel, social interaction and air quality. Te Ara Mua-Future streets is a neighbourhood scale controlled intervention study, initiated by a research team and conducted in collaboration with (and funded by) Auckland Transport, New Zealand Transport Agency and Māngere Otāhuhu Local Board. The aims of the study are to: 1) improve road safety and make it easier and safer for residents to access local destinations on foot or by bike in Mangere, Auckland, and 2) measure safety, health, social and environmental effects of improving streets and routes. This presentation explores mobility-related effects of the intervention from the perspectives of children and disabled people.

**Method/Design/Approach:** Re-designing neighbourhood streets was guided by a set of principles developed through a participatory design process. Views and aspirations of residents of different ages, ethnicities and abilities/disabilities were gathered via stalls in the mall, community workshops, walk and talk interviews and group discussions. Pre and post traffic counts, resident surveys, focus groups, key informant interviews and street video footage have measured changes in perceptions and behaviours.

**Results:** Impacts of the intervention include: slower traffic speeds, less traffic, safer pedestrian crossing behaviours, an increase in mobility-assisted movements, fewer people in wheelchairs reporting mobility difficulties, and parent's reporting it is safer for children to walk or cycle in the neighbourhood.

**Discussion:** Re-designing streets and routes has changed transport behaviour in the intervention area, increased accessibility for mobility-impaired residents and improved parents' perceptions of neighbourhood safety. Residents have a more positive view of the 'look' and 'feel' of local streets but concern around anti-social behaviour remains an impediment to children's independent mobility and use of neighbourhood routes.

**Limitations:** Final analyses of survey data not yet available.

**[E128] Rapid urban intensification under pressure from climate change: a crash programme to rethink New Zealand cities?**

Associate Professor Ralph Chapman, *Victoria University of Wellington*

Is rapid intensification feasible in New Zealand cities? This think-piece exploration takes as a framing scenario of New Zealand by 2030 being in a state of policy panic about how to reduce carbon emissions rapidly enough to meet our 'net zero by 2050' target consistent with the Paris agreement, under international pressure to make emergency reductions.

A central question with that scenario is what contribution to cutting transport emissions can be made by urgently reshaping our cities as much more compact, mixed use neighbourhoods?

How would the benefits (including a variety of co-benefits) of rehousing people over 15-20 years compare with the costs of transforming our cities and suburbia? What would be the perceived advantages and disadvantages? How much higher could housing densities go without major resistance? Would green space be traded off or retained?

Might outer suburbia aim to rely on telework and EVs despite high priced renewable electricity? Or would many urban New Zealanders be content to move into the central city and inner areas to use more sustainable travel modes, despite rising prices of housing there?

This presentation will build on what we know from recent research about New Zealanders' changing preferences for housing, neighbourhoods and travel. Its conjectures will also tease out the author's insights from some years of policy debates about urban planning, the speed and impact of climate change, attitudes to climate change mitigation, and the economics of the energy, housing and transport sectors in New Zealand.

**[E129] Regeneration for Social and Economic Outcomes**

Rachael Cole, Joanna Brain, *Tāmaki Regeneration Corporation*

Tāmaki is New Zealand's only large-scale regeneration programme. The aim of this presentation is to share TRC's experience delivering new neighbourhoods of mixed, mixed tenure housing as part of its redevelopment of 2,500 state houses in Tāmaki.

The regeneration programme is about harnessing the opportunities created by development activity to deliver positive social and economic change. One of the key platforms for the success of the regeneration programme is the creation of mixed tenure communities.

Delivering mixed tenure housing brings design and development complexity, but the rewards are significant. International evidence has found that state housing tenants avoid stigmatisation and good neighbourly relations are reported. This results in strengthened community cohesion, decreased feelings of isolation or loneliness, increased social capital, and greater equality of opportunity (through thriving schools, enhanced health and social service provision).

This presentation will share our experiences over the last five years moving away from mono-tenure developments to the integration of state housing through new medium-density terraced housing and apartment developments.

Implementation has not been without its challenges. Whilst mixed tenure communities are desirable, this involves a great degree of change to the existing community. Placemaking activities are vital to encouraging meaningful interaction, and our more recent neighbourhood designs have encouraged a greater degree of street interaction and creation of local spaces to facilitate connection.

#### **[E130] Free source of heating for housing**

Professor Robyn Phipps, Yu Wang, Mikael Boulic, Chris Cunningham, *Massey University*

New Zealand's housing is typically cold and damp, due to low levels of insulation to hold in any heat, low inputs of heat and a lack of ventilation. Correcting these issues is a significant and difficult task requiring retrofitting of heating appliances, insulation and ventilation systems. Subsidies for insulation retrofits are available and many households have taken advantage of having ceiling and underfloor insulation installed. Methods to introducing heat are urgently required especially for households that experience energy hardship. Further, methods to increase the ventilation in homes are urgently required. The vast majority of homes are reliant on openable windows for ventilation. Many homes are unoccupied during the day time meaning windows are not opened and in periods of cooler weather it is counter intuitive to open windows as this releases heat. The most common ventilation system is the type that take air from the ceiling cavity and push this into the home. However this is not always a clean dry source of air.

Most parts of New Zealand have high sun shine hours even during the winter months. A solar air heater has been trialed on classrooms and was successful for raising the temperature, reducing relative humidity and reducing the use of heaters. This paper discusses the potential for solar air heaters to be used in New Zealand homes.

#### **[E131] Numerical investigation on the melting of nanoparticle-enhanced PCM in latent heat energy storage unit with spiral coil heat exchanger**

Mr Ruiqing Du, WenXin Li, Professor Yong Wang, *Chongqing University*

For latent heat storage (LHS) units with the spiral coil exchanger which are widely used in residential building heating systems, performance is limited by the low thermal conductivities of phase change materials. In this paper, paraffin dispersed with copper nanoparticle were added to enhance the heat transfer rate of LHS unit with a spiral coil heat exchanger. With a 3D numerical model of the LHS unit which was validated against the experimental data, the thermal performance of pure PCM and nanoparticle-enhanced PCM (NePCM) was compared. The simulation results revealed that the heat transfer rate in NePCM was higher than that of pure PCM due to its higher thermal conductivity, and the total melting time was shortened by 19.6% from 10000 s to 8080 s. Furthermore, for the bottom area of unit which occupied less than 5% of the volume of unit, the pure PCM cost 24.3% of total time to melt, while the NePCM in this area was completely melted almost synchronously with the PCM in other parts. The dispersion of nanoparticles significantly alleviated the temperature non-uniformity in the unit. Moreover, for the unit filled with NePCM, the flow rate of heat transfer fluid (HTF) was not recommended higher than 0.75 m<sup>3</sup>/h and the

dispersion of nanoparticles could enlarge the optimum HTF temperature range to 60-70°C comparing to that of pure PCM (60-65°C). Therefore, optimum ranges of HTF inlet temperature and flow rate were proposed and used to control the operating conditions of LHS units reasonably for higher efficiency.

**[E132] Study on VOCs emission model from multiple building materials**

Miss Miao Guo, Associate Professor Wei Yu, Professor Runming Yao, *Chongqing University*

In modern life, more and more people are paying attention to indoor air quality. However, people cannot predict indoor pollutant concentration, which brings difficulties to the treatment of indoor pollutants and affects the health of residents. In the previous research, most of the research on the VOCs emission model only focused on the emission of a single building material, and did not consider the situation of multiple building materials. Based on the previous studies, this paper proposes an emitting model of VOC from variety of building materials, and solves the numerical solution, as well as plots the concentration curve of pollutant concentration in space. This new numerical solution is applicable by comparing with other traditional model solutions. The 1- cubic-metre chamber is adopted to test performance of building materials and analyze the key parameters of the model. It can be concluded from the experiment that this model can reflect that the inhibition when multiple materials emit VOCs Finally, based on the model, a software platform was compiled. So people can predict indoor air quality after decoration.

**[E133] Integrated thinking is essential for housing sustainability. Lessons from the urban development world and wider.**

Mr Ian Short, *Housing New Zealand*

There are increasing demands on those funding and delivering housing and communities to factor in a variety of considerations ranging from the global, such as climate change and resource scarcity, through to the local, such as community cohesion and mental health.

At the same time, many urban areas are facing the challenges of outdated infrastructure, demand for more and better housing, environmental degradation and a pressing need to improve economic and social wellbeing.

In response, urban stakeholders are increasingly viewing their cities and towns as complex, interrelated systems that currently operate in inefficient silos. With shrinking public budgets, the focus is on how stakeholder organizations move to an integrated approach to planning and investing in our cities and communities. By looking at cities as interrelated systems rather than individual components, it is easier to identify the maximum economic, social and environmental returns and how to deliver them cost effectively.

This urban focus is part of a growing global consensus that an integrated approach is required and that it will deliver much more with what we currently have. This is seen in the corporate world with initiatives like the International Integrated Reporting Framework, in social services with social impact

bonds, in international development with the UN's Sustainable Development Goals and with the NZ government's Living Standards Framework.

While integrated approaches can deliver significant value, they also add complexity and risk so the default for many organisations is to focus on what they control only.

Methodologies and tools are being developed and applied across sectors that are enabling better integrated thinking, decision making and reporting.

This presentation will highlight some practical examples of where organisations in New Zealand and globally are pushing the boundaries in supporting better integrated solutions. It will include an understanding of the drivers, the approaches taken and where there are limitations and challenges.

#### **[E134] Evaluating the Tamaki Regeneration**

Lara Rangiwhetu, Professor Philippa Howden-Chapman, Associate Professor Nevil Pierse, Dr Elinor Chisholm, Ed Randal, Ian Short, *University of Otago, Wellington*

Tāmaki Regeneration Company (TRC) is in the process of redeveloping 2,500 social houses into approximately 7,500 mixed houses, with at least as many social units as before, to create 'an awesome place to live'. Evaluating the impact on residents' wellbeing is therefore key, to see whether they have met their intended aim.

Evaluations can help identify what has worked or is working well, or not and why, and can offer suggestions for future approaches. This is particularly important with respect to social housing initiatives and resident wellbeing, as in New Zealand there is a limited evidence base to influence sound policy decision making with regards to these large scale investments.

The University of Otago, Wellington's, He Kainga Oranga team, have been working alongside TRC to develop an evaluation framework. This has involved developing theories of change in 7 areas: neighbourhood regeneration, housing management and organisation, economic development, affordable housing, Tāmaki Response, the environment and placemaking, which sit under an overarching logic model. The logic maps created depict step changes between the intended inputs and desired people, place and systems outcomes. Measures have been developed alongside this process for each step change, and collection of baseline data has commenced with a quasi-experimental approach proposed.

This presentation will discuss the development of the evaluation framework to date. As the development of Tāmaki has a 15-20 year timeframe, it is expected that the specifics of the evaluation will undergo a few iterations, and that due to the staggered rebuild approach, TRC will be able to apply learnings from the evaluation over time.

#### **[E135] Measuring housing quality in New Zealand – the journey so far**

Rachel Felgate, Katie Stevens, Ian Newman, Rosemary Goodyear, Vicki White, *Ministry of Business, Innovation and Employment, Statistics NZ and BRANZ*

Housing quality is a known gap in New Zealand's official statistics. Following a review of this country's Tier 1 statistics in 2012, Cabinet directed the then Department of Building and Housing, in conjunction with Statistics New Zealand (Stats NZ), to develop the Tier 1 statistic on housing quality. The Ministry of Business, Innovation and Employment (MBIE) initiated this work recently.

Currently there is no single definition of housing quality nationally or internationally, and no comprehensive set of up-to-date data on the condition of housing stock in New Zealand. This presentation will discuss MBIE, Stats NZ and the Building Research Association of New Zealand's (BRANZ) joint project to design an approach to measuring housing quality in New Zealand.

This work aims to develop statistics that enable changes in housing quality to be monitored and support better understanding of the relationship between housing and wellbeing.

This presentation will cover the opportunities, challenges and lessons the team has experienced in its first nine months of:

- developing an agreed definition of housing quality in New Zealand
- identifying the data that needs to be collected and reported on to measure housing quality
- using data from multiple sources – survey, census and administrative data – to create a data infrastructure about housing quality.

The presentation will conclude with a description of the 'next steps' in our journey to develop robust and enduring statistics about housing quality.

## Poster presentations

### **[E003] Optimization of floor elements to cover the heating needs of buildings using solar collectors**

Professor Georgios Florides, *Cyprus University of Technology*

To upgrade the Building energy efficiency and lower carbon emissions solar energy can be utilized and stored in building components to cover the heating needs of the building during the cold months. A sustainable design results when the various components are optimized.

In this study the foundation concrete in new buildings is examined as a storing material, where the heat gains of a flat plate collector array on the roof of the building are driven and accumulated.

A typical house was chosen for the study with insulated walls facing the four cardinal points. Solar collectors are placed on the house roof facing south with an appropriate area and slope. A circulation pump is used between the collectors and the foundation concrete when temperature exceeds 40°C. An appropriate TRNSYS model is constructed, providing the hourly solar collector energy and building's thermal load. Weather input parameters were chosen for typical temperate climates.

Furthermore, COMSOL Multiphysics is used to examine the thermal storage of the building's concrete foundation. The hourly results from the solar collectors in TRNSYS are used as input for piping in the concrete, where the house thermal load is used on the top of the concrete foundation. A thermostat like parameter is used to control the temperature on the top of the building's foundation by varying the input energy provided by the solar thermal collectors.

Finally, when storing of the solar thermal energy in the buildings foundation is achieved, the simulations are varied to examine the effect of various parameters, such as the effect of the concrete thickness, the amount of heat available and that which is stored, as well as the controlling technique. Results indicate that the proposed system, when optimized, can cover the building's heat requirements during winter in a sustainable way.

### **[E005] Experimental study on the applicability of solid particles used in dust loading performance evaluation experiments for HEPA filter media**

Zhang Wanyi, Deng Shiming, Lin Zhongping, *Tongji University & the Hong Kong Polytechnic University*

HEPA filter media have been used in many fields to maintain a super clean indoor air environment for various purposes. Considerable attention has been paid to the dynamic pressure drop of fibrous HEPA media that directly affects the energy consumption of a ventilation system. However, there is no consensus about the experimental aerosols used in the dust loading performance experiments of HEPA media. This paper aims to experimentally examine the applicability of solid aerosols used in dust loading performance test from three perspectives including size distribution, sensitivity to humidity and stability of resistance which are selected among all the factors that influence the dust loading process of HEPA media according to systematical analysis. And three kinds of representative aerosols/particles including ISO 12103-1 A1 road dust, polydisperse KCl aerosol, polydisperse spherical SiO<sub>2</sub> aerosol were used in the experiments. Results show that, A1 dust deviated greatly

from the aerosol size distribution in real life environment of HEPA filters while KCl aerosol and SiO<sub>2</sub> aerosol could be adjusted to fit the distribution well. Besides, the pressure drop of HEPA media loaded with KCl particles decreased slowly when the loaded medium was placed still but decreased significantly when encountered with high humidity air flow, which probably results from the inner structural collapse of dust fibre and cake. Finally, polydisperse spherical SiO<sub>2</sub> aerosol performed well in all the three experiments and therefore is recommended as the experimental aerosol for the dust loading performance test of HEPA media.

### **[E013] SVOC Adsorption and Ozone Reaction of House Dust in Residences**

Nao Maeta, Naoki Kagi, *Tokyo Institute of Technology*

Semi-volatile organic compounds (SVOCs) are concerned about health effects, suggesting a relation to allergic symptoms. SVOCs have many sources in buildings, such as plasticiser and flame retardant of interior materials. They are easily adsorbed onto house dust in indoor environment. In recent years, they have been reported that high concentration SVOC was also detected in the filter dust of the air conditioner as well as floor dust, so it is necessary to consider about filter dust for SVOC contamination in indoor environments. Although it is suggested that floor dust is changed to another compound by ozone, filter dust may be reacted with ozone as well. Filter dust is easy to contact with indoor ozone when using air conditioners, and it may become new contamination sources in indoor environments. The purpose of this research is to clarify the actual pollution state by SVOC and reactivity to ozone for floor dust and filter dust of residential air conditioner in houses.

In the field measurements in houses, high concentration SVOCs were detected in both filter dust and floor dust. Especially, DEHP in dusts was the highest concentration in any samples. It was found that there is a positive correlation between the sum of the SVOC concentrations in filter dust and ones of floor dust. And filter dust was associated with dust age.

In the ozone exposure experiment for house dust, ozone decomposed high molecular compounds and increased low molecular weight compounds that could lead to the effect on indoor air quality. There was a difference in the amount of change between filter dust and floor dust. Even with test house dust, four kinds of substances behave similarly to actual dusts. It was also shown that humidity in air could affect the reaction of SVOC and ozone.

### **[E015] Effects on Human Physiological and Psychological Reaction during Sleep by two types of Cooling System**

Yuko Ogawa, Yasuyuki Shiraishi, *University of Kitakyushu*

Since the sickroom is the place where patients live all day and night, it is necessary to prepare a patient-oriented medical care environment. Especially, the human physical and mental condition is easy to be affected by indoor thermal environment during sleep at night because the thermoregulation function decreases. However, there are many cases using convective air conditioning system as present system of sickrooms. In the case of such system, it is considered that the indoor thermal environment may have the bad influence on the patient's physical condition and

the physical activity in their awake because of the influence of draft and the excessive change of room temperature. Recently, the ceiling radiation air conditioning system has got an attention in Japan. This system serves to maintain indoor environment without vertical temperature difference and draft. Therefore, this makes a comfortable thermal environment.

In this study, we carried out subject experiments for sleeping person in summer using the laboratory which simulated a sickroom with the convective system and the ceiling radiant system. The subject of our study is to reveal the influence on human physiological and psychological responses by the different methods of cooling system. Eight healthy young males slept in laboratory.

As a result of physiological quantity, the skin temperature of hands and feet without beddings was low in the case of convective system. Furthermore, the sleep efficiency evaluated by electroencephalogram signals was higher in the case of ceiling radiant system. Because the subjects had shorter sleep onset latency and arousal time, and longer deep sleep time. As a result of psychological quantity, the sleep state that subjects evaluated after getting up in the morning was better in the case of this system.

These studies showed that sleep quality of ceiling radiant system is better than that of convective system.

#### **[E016] The Influence of Mycotoxin to Other Fungus Growth Characteristics Based on Competition Principle**

Mizuki Niimura, U Yanagi, Naoki Kagi, *Kogakuin University*

Although there are, in nature, 100,000 or more species of fungi, only about 100 have been detected in indoor environments including dwellings. This limit in the number of contaminating fungi may reflect competition between fungi. Competition among species is a mechanism whereby sources of nutrition are secured. thus, growth inhibition of other fungi by mycotoxins may provide a competitive advantage to the toxin producer. This study addresses growth inhibition of indoor fungal species by mycotoxins.

The fungi used for this study were *Cladosporium halotolerans*, *Penicillium chrysogenum*, *P. expansum*, *Aspergillus restrictus*, *Acremonium fusidioides*, *Wallemia sebi*, *Chaetomium globosum*, *Eurotium amstelodami* and *Rhodotorula mucilaginosa*, as well as the mycotoxins of patulin, T-2 toxin and Sterigmatocystin were used.

In this study, growth of a fungi was remarkably controlled by Sterigmatocystin. Moreover, it became clear that T-2 Toxin can control growth of most of fungi in three kinds of mycotoxin.

This study was based on the results obtained by the authors in previous field surveys. Notably, indoor fungal contaminants typically consist of relatively few species. The above observation suggests that competition is occurring among fungi in the residential environment.

### **[E018] Verification of a Retrofit Introducing a Radiant Cooling and Heating System for an Aged Building**

Saki Nishida, Yasuyuki Shiraishi, *University of Kitakyushu*

In recent years, various attempts to rebuild and refurbish buildings have been tried for the purpose of accumulating good social property and effectively utilizing building stocks. However, aged buildings, cause deterioration of the indoor thermal environment and increase of energy consumption, because of low insulation performance of the building and aging of air conditioning equipment. In particular, in the office space, it is pointed that the quality of the indoor environment affects not only the comfort of the office worker but also the intellectual productivity and health. When refurbishing, it is necessary to continuously consider improvement of indoor environment and energy saving performance.

In this research, as a repair plan for air-conditioning equipment, we propose ceiling radiant cooling systems which attract attention in office building in recent years, also and aim to show its effectiveness in advance. We conducted actual measurement of the indoor environment in summer and considered the introduction of radiant cooling systems for the aged office building in Japan. Moreover, CFD analysis for this building was carried out and the results before and after renovation were compared.

The following results were obtained:

- 1) In the measurement, it was confirmed that there was a concern of draft, as well as a difference in temperature distribution by area. It was also suggested that the heat source facilities were operated satisfactorily and well water could be utilized as a heat source.
- 2) The results of CFD analysis revealed the ununiformity of the present thermal environment, and it was shown that these are solved by introducing radiant cooling systems.
- 3) Furthermore, by insulating the outer covering of this building and introducing LED, we confirmed that it is possible to achieve a comfortable indoor environment even if the radiant cooling capacity is reduced, and that energy saving effect can be expected.

### **[E073] Analysis on Indoor Air Environment and Building Age of Houses in Japan**

Ryo Nishiyama, Kotaro Kawata, Masaki Tajima, *Kochi University of Technology*

For the purpose of grasping relationships between thermal insulation performance and indoor air environment of wooden detached houses built in mild climate region and hot humid region in Japan, an actual survey has been conducted. 15 houses' indoor air temperature, relative humidity and carbon dioxide concentration in summer and winter were obtained from FY 2015 to FY 2017. The obtained data were divided into two groups such as belonging to newer houses, which are constructed or retrofitted after 1999 whose envelope insulation performance is equivalent to the latest Energy Saving Standard of Japan, and belonging to older houses which are constructed or retrofitted before 1998. Using the reference value of the Act on Maintenance of Sanitation in Buildings as an index, air temperature, relative humidity, specific humidity and carbon dioxide

concentration in main living rooms are statistically compared between the two groups and discussed.

Conformity ratio for the Act on Maintenance of Sanitation in Buildings of air temperature is higher for the newer houses in both summer and winter. As a result of statistical analysis, a significant difference ( $p < 0.05$ ) on the conformity ratio of air temperature is found between the two groups. The air temperature difference between the two groups in winter is bigger than summer.

Median specific humidity of newer houses is higher in winter; however it is lower in summer. Although, the conformity ratio of relative humidity in newer houses is lower in both summer and winter.

Median carbon dioxide concentration of newer houses is lower than older houses in summer; however it is higher in winter. Same results are shown just using data that is not including houses employing unvented combustion appliances as heaters.

#### **[E077] Field survey on bedroom thermal environment and sleep quality in Japan**

Hiroataka Asakura, Toshiharu Ikaga, Yukie Nakajima, Emi Morita, Daisuke Hori, Shinichiro Sasahara, Ichiyo Matsuzaki, Masashi Yanagisawa, Hiromasa Tsujiguchi, Akinori Hara, Sakae Miyagi, Hiroyuki Nakamura, *Keio University*

Background: Sleep disorders can be a trigger for lifestyle diseases such as myocardial infarction and cerebrovascular disease leading to worsening life prognosis. Quality of sleep is closely related to indoor environment. In particular, thermal environment strongly affects thermal sensation and temperature regulation during sleep. Although it is reported that the acceptable room temperature range is 13 to 28 °C, people living in rural areas often sleep in a cold environment near 0 °C during winter. The objective of this study was to clarify the influence of bedroom thermal environment in winter on sleep.

Methods: Field surveys were conducted in real-life situations during winter in Shika, Ishikawa Prefecture, Japan. This field study involved 383 people over 40 years old. Participants completed a self-report questionnaire about personal characteristics, lifestyle habits, sleep quality, and perceived bedroom thermal environment in their home during winter. Regarding sleep quality, we specifically asked about difficulty falling asleep, waking midway through the night, waking early in the morning, and overall sleep quality. Moreover, the temperature of the bedroom were measured with thermometers. In the analysis, participants were classified into a warm group and a cold group with the median temperature for all participants as a threshold.

Results: The mean temperature for each participant during sleep were 10.8 °C. The relationship between the bedroom thermal environment and the subjective sleep quality evaluation was examined by using binomial logistic regression analysis. A cold group had a 2.19 times higher risk of difficulty falling asleep than a warm group ( $p = .071$ ).

Conclusions: Cold were associated with worse sleep quality. These findings suggest that housing design to keep the bedroom environment mild helps to improve sleep quality.

### **[E083] Field measurements of ultrafine particles by cooking activities in residential houses**

Naoki Kagi, Mebuki Furutani, *Tokyo Institute of Technology*

Particulate matter (PM) is one of the main indoor air pollutions, and it can cause a wide range of diseases that lead to a significant reduction of human life. The size of particles has been directly linked to their potential for causing health problems. The health effects of PM<sub>10</sub> and PM<sub>2.5</sub> are well known to adverse respiratory and cardiovascular health effects. As particles decrease in size, nano size particles are also hypothesized to increase acidity and their ability to penetrate into the lower airways. Since most people spend the majority of their lives indoors, we are exposed to the aerosols in indoor air. And it is essential for exposure control to confirm particle matter of outdoor origin and particle matter generated by indoor sources so that characterization and emission of indoor sub-micron aerosols have been of great interest.

This study aimed at investigating of the characteristics of ultrafine particle concentrations and size distribution during different activities, especially cooking, in residential houses. We monitored particle size number concentrations of ultrafine particles in dining rooms in 4 houses. We also carried out the detailed measurements of particle generation during cooking in the experimental kitchen and evaluating the particle leakage from the kitchen to dining room during cooking.

In the field study for dining room, cooking activities affected indoor particle concentration, especially UFPs with a particle size of 100 nm or less, which has a large adverse effect on the human body. Even in dining room, the concentration of ultrafine particles increased by emission in the kitchen.

### **[E084] Increase of Chemical Concentration by Indoor Negative Pressure in Japanese Detached Houses**

Hoon Kim, *National Institute of Public Health*

Japanese detached houses traditionally have been built of plenty of woods and frequently equipped only with the exhaust ventilation system. In recent years, there is a strong possibility that the negative pressure can be formed indoors by using an exhaust fan, as the air tightening technique has improved.

In this study, c-value (airtightness ; equivalent leakage area), ventilation volume and air concentration of chemicals were measured at bed and living rooms in the 11 newly built wooden houses in order to investigate the infiltration characteristics of chemicals from concealed spaces before and after experiencing a negative pressure.

As a result, c-value ranged 0.1 to 3.0cm<sup>2</sup>/m<sup>2</sup> as showing variations depending on house suppliers, and it complied with the relevant standard that c-value should be 5.0 cm<sup>2</sup>/m<sup>2</sup> or less for the airtight house in Tokyo and neighboring regions.

There were not any other individual chemicals exceeding the Japanese IAQ guideline except that acetaldehyde surpassed the guideline at only one house. Meanwhile, TVOC exceeded the tentative criterion 400µg/m<sup>3</sup> from most of measured rooms. In addition, dichloromethane, which the discontinuation recommendation of use has been issued due to a strong human toxicity, was detected at high levels in five houses as showing the maximum concentration of over 6,000µg/m<sup>3</sup>.

After depressurization, the concentration increase rate at bedrooms tended to surpass that of living rooms. TVOC concentration increased by  $320\mu\text{g}/\text{m}^3$  on average.

Any significant correlation was not observed among “types of ventilation system, c-value (airtightness performance), differential pressure and ventilation rate” and “concentrations and concentration change rates of chemical substances”.

It was apparent that indoor negative pressure could be formed by operating the kitchen range fan in airtight houses and the infiltration of chemicals from concealed spaces and/or building materials could lead to an increased indoor concentration regardless of the type of ventilation system.