DIRECTOR'S WELCOME

Welcome to our latest newsletter, where we showcase some of our research in clean water technologies that has captured interest across the wider general media.

Over the past few months we have had the pleasure of welcoming a number of leading international researchers to our Hub, including experts from John Hopkins University (USA), the Universities of Oxford and Manchester (UK) and Tianjin University in China, all of whom shared their experience in our ongoing seminar series.

In June we hosted the *Australia Workshop on Membrane Technologies for Biomedical Applications* together with CSL Behring in Geelong. Speakers included Dr Hung Pham (CSL Behring Australia), Dr Joe Bertolini (CSL Behring Australia), Professor Lingxue Kong (Deakin), Professor Wei Duan (Deakin), Dr Ludovic Dumee (Deakin), Mr Andrew Rau (Deakin), Dr Yoni Sharon (Monash), and Professor Huanting Wang (Deputy Director of the Hub) and myself.

I hope you enjoy our latest newsletter to learn more about our research and engagement activities.

Professor Xiwang Zhang

(Hub Director)

Hub CI nominated as finalist for 2019 Eureka Prize

Hub Chief Investigator Associate Professor Matthew Hill and his team have has been nominated as a finalist in this year's Australian Museum Eureka Prizes.

The Broad Spectrum Respiratory Canister Team have been nominated for the category *Defence, Science and Technology Eureka Prize for Outstanding Science in Safeguarding Australia.*

This collaborative project with CSIRO, Defence Science and Technology Group, and Spectrum Innovation Pty Ltd has led to the development of new respirator canister technology that can protect military personnel from weaponised toxic chemical gases and vapours.

This offers a step change from existing technology, which sometimes provides minimal protection, giving soldiers a greater chance to safely complete their mission.

The Australian Museum Eureka Prizes honour excellence across the areas of research and innovation, leadership, science engagement and school science, and are presented annually in partnership with some of the country's leading scientific institutions, government organisations, universities and corporations.

Hub poster competition

As part of an initiative to showcase research carried out across all nodes of the Hub, we are running a poster competition.

All researchers are invited to submit a scientific poster and one page PowerPoint Presentation (PPT) highlighting a research outcome.

The poster and PPT will be used to promote our research to the public (both softcopy and hardcopy) to the public. Please do not include any confidential information.

Three prizes will be awarded to the top 3 best posters:

First Prize - $500 and certificate

Second Prize - $300 and certificate

Third Prize - $200 and certificate

The poster evaluation criteria are:

1. Clear communication of the poster that can be understood without the need of an accompanying oral presentation
2. Overall visual presentation - balance of text, figures and space, colour and fonts, quality of the graphics
3. Content - clearly written, logical sequence, appropriate and relevant content, accuracy of the content
4. Legibility - easy to read
5. Grammar/spelling

Please email arc-eesep@monash.edu for more information

Creating a better water future

In a world-first breakthrough, researchers from the Hub together with colleagues from CSIRO, The University of Melbourne and The University of Texas at Austin, have established an unprecedented new method to filter contaminants from groundwater and industrial wastewater, opening up new options to provide safe, clean drinking water in the developing world, and to protect the natural environment from industrial water pollution.

In their study published in *Nature Communications*, the international research team outline their control method to separate particular negatively-charged ions from water using Metal-Organic Frameworks (MOFs).

MOFs are an advanced nanostructural material comprised of porous crystals with metal ions joined together by organic linkers. MOFs contain molecular-sized pores that can store, separate, release or protect many substances, and can be scaled up to suit a variety of industrial purposes.

An extremely flexible and customisable technology, there are now over 60,000 types of MOFs synthesised, with unlimited potential for researchers to identify further customisations to suit particular industry needs.

Led by Professor Huanting Wang (Hub Deputy Director) and Dr Huacheng Zhang from the Department of Chemical Engineering at Monash University, in collaboration with Dr Anita Hill (CSIRO) and Associate Professor Matthew Hill (CSIRO and Monash University), Professor Benny Freeman (The University of Texas at Austin), and Associate Professor Jefferson Zhe Liu (The University of Melbourne), the team developed a MOF with precisely tuned pores of a size and chemistry to be compatible with the selected anion.

When passing over the filter material, the selected anion was attracted to the pore, and easily passed through with little force or resistance, while other anions were largely unable to pass through the pores.

This is unprecedented breakthrough differs from other water filtering methods, where all forms of anions are removed and filtered to extract the unwanted substance from the water. This is a costly and energy-intensive process that often requires some of the filtered anions to be added back into the water once the unwanted anions are removed.

In their research paper, *Fast and selective fluoride ion conduction in sub-1-nanometer metal-organic framework channels*, the team demonstrated the success of this technique by identifying a MOF that showed high selectivity for fluoride anions over other anions.

Although the World Health Organisation guidelines determine fluoride to be safe for human consumption in levels up to 1.5 mg/litre, many developing countries have higher natural fluoridation levels in their groundwater, yet lack resources and cost-efficient methods to filter the water effectively. Furthermore, the agriculture industry is increasingly searching for ways to clean up water pollution caused by fertiliser and pesticides, particularly in areas where contaminated run-off is at risk of entering rivers and the ocean.

"Based on our research, we now have the capability to produce simple and affordable water filters that can be used safely and effectively anywhere in the world," said Professor Wang. "This is a significant outcome for people in developing countries who lack access to safe, clean drinking water, and for industries who are increasingly seeking ways to reduce the cost of their environmental impact. Our findings also prove we have the capability to determine the most effective filtering material and method to suit a specific material, or a particular industry need."

"The ability to selectively remove targeted ions from water with such high levels of specificity provides new pathways to address fundamental challenges in energy-efficient production of fit-for-purpose water for a variety of water and energy applications," said Professor Freeman.

"This research work also demonstrates the essential value of collaboration between experiments and simulations, which helps us gain molecular-level insights into the ion transport process," said Associate Professor Liu. "It has also helped to identify the critical role of the fluoride binding sites in the MOF nanochannels on the high ion selectivity and conductance."

Associate Professor Matthew Hill added, "This research outcome is a great example of using high-tech, next-generation technologies to assist in the transition to a circular economy, where long-term management of wastes can generate new industries, while also protecting the environment."

First published: https://www.monash.edu/engineering/about-us/news-events/latest-news/articles/2019/creating-a-better-water-future

PUBLISHED PAPER

Fast and selective fluoride ion conduction in sub-1-nanometer metal-organic framework channels

Xingya Li, Huacheng Zhang, Peiyao Wang, Jue Hou, Jun Lu, Christopher D. Easton, Xiwang Zhang, Matthew R. Hill, Aaron W. Thornton, Jefferson Zhe Liu, Benny D. Freeman, Anita J. Hill, Lei Jiang & Huanting Wang

Nature Communications 10: 2490 (2019)

READ MORE

Hub research excellence awards

Following the scientific seminar by Professor Michael Guiver, the Hub celebrated the New Year with our Excellence Awards presentations. Also in the attendance were Professor Michael Guiver (Tianjin University), Professor Mikel Duke (Victoria University), Professor Ana Deletic (University of New South Wales), Professor Lingxue Kong (Deakin University), Dr Zongli Xie (CSIRO), Professor Huanting Wang (Monash University) and Professor Xiwang Zhang (Monash University).

Congratulations to the winners of 2018 Excellence Researcher Awards! The winners are:

Early Career Researcher Category:
First Prize: Ms Liyuan Zhang (Monash)
Second Prize: Ms Xiaofang Chen (Monash)
Third Prize: Ms Bhuvana Shanbhag (Monash)

Postgraduate Researcher Category:
First Prize: Mr Federico Volpin (UTS)
Second Prize: Mr Meipeng Jian (Monash)
Third Prize: Ms Yue Liu (Monash)

Hub CI strengthens collaboration with Activated Water Technologies as new project announced

As part of their Strategic Portfolio expansion, Parkway Minerals and CPC (Consolidated Potash Corporation) have announced further support of a collaboration between Victoria University and their subsidiary, Activated Water Technologies (AWT).

AWT and Victoria University (via the Hub) are strategic partners and have been awarded several grants to explore aMES™ technology on brine processing.

aMES™ is a next-generation (activated) mineral extraction system. The technology is suitable for recovery of minerals, reagents and water from aqueous solutions including desalination, and industrial and mining waste streams. Mineral extraction is facilitated by systematically concentrating minerals through the removal of water from mineral rich solutions through a proprietary membrane based process.

The aMES™ application rationale includes: a) potential to rapidly develop a more capital efficient and sustainable potash production operation compared to conventional development pathways; b) eliminating the requirement for flotation, process steam, gas pipeline and a freshwater bore field, which collectively represent major costs in the traditional potash production flowsheet; c) potential to recover magnesium salts as a by-product. The team is exploring an extension of the aMES™ technology to other projects other applications.

This project is led by Prof Mikel Duke (Victoria University) and Mr Bahay Ozcakmak (AWT), with Dr Peter Sanciolo, Dr Xing Yang and Mr Jiean Luo part of the research team.

READ MORE

A promising path to improve sustainability of water treatment systems

A team of researchers led by Professor Xiwang Zhang (Hub Director) has collaborated with Oxfam to develop a small-scale desalination and water purification system. This compact prototype uses reverse osmosis powered with solar energy to produce clean water. The OMP Water Purification Prototype may be the solution to bring clean water to remote areas that lack an adequate and safe water supply.

Access to a clean and reliable water supply is one of the major development challenges of our time. Water is central to life and is becoming dangerously scarce and unsafe globally. Population growth, changing consumption patterns, increasing water demand for agriculture, and climate change, are threatening fresh water supplies. A major problem is the deterioration of ground water quality due to rising sea-water levels associated with climate change and over-exploitation, resulting in water salinity in many coastal and riverine settings. Surface water contamination with micro-pollutants is also an emerging issue globally, due to municipal, industrial and agriculture waste water.

This challenging situation is reflected in the lack of progress towards the UN's Sustainable Development Goal (SDG) 6 on ensuring availability and sustainable management of water and sanitation, specifically 6.1, which relates to universal and equitable access to safe and affordable drinking water for all by 2030. The latest report has shown that the world is not on track, with over 2.8 billion people still not having access to safe drinking water. The consequences are dire for those affected; the World Health Organisation (WHO) estimates that contaminated drinking water causes 500,000 diarrheal deaths each year. A recent study has shown that drinking saline water is associated with elevated blood pressure, with adverse effects for women during pregnancy on maternal and fetal outcomes.

The alarming increase in water scarcity across the world has led to an exponential growth in water desalination from unconventional sources, including sea and brackish water. Globally, the majority of desalination systems use reverse osmosis (RO) due to its excellent performance in impurity removal. The rapid progress in membrane technology and treatment processes is helping to meet some of the increased demand for water in Australia and internationally. There are currently over 20,000 desalination plants operating in 120 countries, however, these systems are capital intensive, and require high-energy inputs and specialised maintenance procedures to function sustainably.

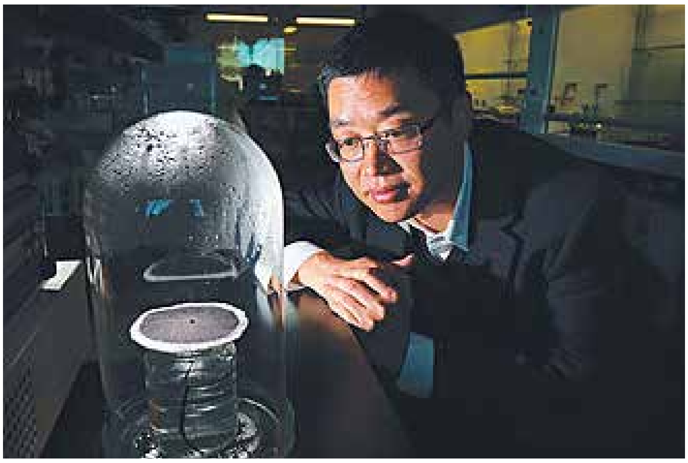
Future growth in desalination and water purification is most likely to rely on the use of brackish water, which has far lower concentration of solids than seawater, and involves cheaper process. Wastewater reuse for a circular economy is another potential solution.

The Oxfam road-map for small-scale desalination, based on an overview of existing and emerging technologies in South Asia, provided the key considerations for these systems in terms of minimum production capacity from brackish water sources, low initial cost, low energy consumption, low maintenance cost, and scalability within existing market systems. A study in the Sambhar Salt lake region of Rajasthan, India found that small-scale reverse osmosis (RO) using a renewable energy source is among the most effective technologies, with demonstrated technical and economic feasibility. The study identified the emerging technology, Capacitive Deionization (CDI) that has higher water recovery and lower energy consumption than RO in Madras, India. This CDI model utilises direct current generated by an off-grid solar panel to separate soluble ions from water under electric field, and consumes much less energy than pushing water through a membrane in RO systems. The WIRC is developing an affordable water purification system using CDI for East African communities to remove excessive fluoride in water to address significant health problems, such as crippling bone disease.

The main producers of these micro-desalination and water purification technologies are not-for-profit, commercial and private desalination companies that partner with universities, philanthropists, governments, non-governmental organisations, and international development organisations. The water production capacity of small-scale water purification units vary from 20 to a few thousand litres per day. Various water sources can be treated by these purification units, including brackish water with salt content in the range of 1,000-35,000 parts per million, sea water, contaminated water, and freshwater from lakes and rivers. Most of these systems are within 200 kg range and can easily be assembled and transported with a hand trolley, making them suitable for remote areas. A few have already been trialled and used in small communities. For instance, the solar-driven Low Pressure Reverse Osmosis (LPRO) developed by Moerk Water has serviced thousands of people in Kenya, Myanmar, Papua New Guinea, the Solomon Islands, Somalia, Tanzania, Vanuatu and Australia. Barefoot College, a voluntary organization, has installed six solar-powered desalination plants in India and supported approximately 1,000 people. Swiss Fresh Water started a pilot project in Senegal in 2011 and since then has kept installing purification machines for private and community markets. Plimmer is being marketed by Idropan Australia, and can produce up to 2000 litres of fresh water/day, with saline water up to 1250 parts per million. Other producers such as Trunz Water system, Boreal Light GmbH, Water Source Australia, Aquvio, Tata projects, Innovative Deionization, and Aqua EWP, among others, are rapidly growing and serving hundreds and thousands of people.

Several of the ongoing initiatives are using market-based approaches with encouraging results. For instance, a recent study on the use of water kiosks in Athi River and Rongai, Kenya to increase access to safe and affordable drinking water has shown improvements in living standards, health and income. However, considerable research needs to be conducted to demonstrate replicability at scale. When combined with specific actions to strengthen national policies, regulatory frameworks, and governance mechanisms, these initiatives are more likely to be effectively scaled up and sustained. As the Oxfam road map highlights, beyond the technology itself, the key elements of success include enabling the maintenance, supply of consumables, appropriate disposal, and sufficient cost recovery systems.

In the media



Professor Xiwang Zhang's important research has recently appeared across diverse media outlets, including a recent feature in *The Australian*.

Exposure of our research into the mainstream media is an important element of our outreach.

The number of media mentions of this work is testament to its significance and potential widespread impact.

EXTRACT FROM *THE AUSTRALIAN, 24 July 2019*

Monash University researchers have found a new way to desalinate water using only sunlight and a few cheap materials.

The new system can be built for a few dollars and has an operating cost of virtually zero, according to chemical engineering professor Xiwang Zhang, who led the research team.

It works by evaporating water off a black disc that is heated by the sun, and the steam is captured by a transparent dome that sits over the top.

While it does not have the capacity to desalinate water for a town or a city, it could easily handle the drinking water needs of a family or a village, said Professor Zhang, who is also director of the ARC Research Hub for Energy-efficient Separation.

The new system is more effective than other solar-powered desalination systems because it doesn't require any extra energy input and it can work for a long period without maintenance.

It avoids a problem that typically affects solar evaporation systems: the accumulation of salt crystals on the evaporation surfaces, which reduces efficiency and eventually stops the process.

In the Monash device the salt crystallises only at the outside of the disc because of a special layered structure of the evaporation disc.

"This design leads to salt crystallisation only at the edge of the evaporation disc, spatially isolated from the major part of the active surface for water evaporation. By weakening the binding force between the salt crystals and the evaporation disc, the salts fall off automatically under gravity," says the paper, titled Spatially Isolating Salt Crystallisation from Water Evaporation for

Continuous Solar Steam Generation and Salt Harvesting, and published in the journal *Energy and Environmental Science.*

The system has run successfully for more than 600 hours of continuous operation under artificial illumination that resembles sunlight.

Professor Zhang said the lsq m of the system could generate 6 litres to 8 litres of water a day when the sun was shining, with almost 100 per cent salt removal.

His team created the system using cotton thread to carry saline water upward, using capillary action, to the centre of the evaporation disc.

Filter paper traps the pure water, pushing the salt to the edge of the disc where it crystallises.

The system has another advantage over the energy-hungry reverse osmosis desalination systems that have been installed, at high cost, to drought-proof many of Australia's major cities.

Unlike reverse osmosis, which captures the salt in a membrane, evaporation does not produce highly salty brine, which can be an environmental hazard.

Professor Zhang said the technology also had the potential to be used to purify waste water and mine tailings.

"We hope this research can be the starting point for further research in energy-passive ways of providing clean and safe water to millions of people, illuminating environmental impact of waste and recovering resource from waste," he said.

Professor Zhang said it also had great potential to ease the growing problem of water security, with more than 800 million people across the world believed to lack clean water.

The current energy-intensive approaches to water treatment use about three per cent of the world's energy supply.

Tim Dodd, Higher Education Editor

OTHER MEDIA
Water solutions without a grain of salt

Science Codex - https://www.sciencecodex.com/

Health Medicine Network - http://healthmedicinet.com/water-solutions-without-a-grain-of-salt/

7th Space - http://7thspace.com/headlines/911638/water_solutions_without_a_grain_of_salt.html

ScienceMag - https://scienmag.com/water-solutions-without-a-grain-of-salt/

Science Daily - https://www.sciencedaily.com/releases/2019/07/190723163940.htm

VIDEO, Behaviour Works Australia - https://www.youtube.com/watch?v=PgE6F8h3RzA&feature=youtu.be

PUBLISHED PAPER

Spatially isolating salt crystallisation from water evaporation for continuous solar steam generation and salt harvesting

Yun Xia, Qinfu Hou, Hasan Jubaer, Yang Li, Yuan Kang, Shi Yuan, Huiyuan Liu, Meng Wai Woo, Lian Zhang, Li Gao, Huanting Wang and Xiwang Zhang

Energy Environ. Sci., 2019,12, 1840-1847

READ MORE

Visitors to the Hub

Water Research Australia (WaterRA) Visit

Karen Rouse and Kathy Northcott from WaterRA visited the Hub in June 2019. Professor Zhang led them on a tour of the Hub's laboratories in the Green Chemical Futures building and Chemical Engineering building. Following the tour, an informative discussion was held between WaterRA and EESep Hub to explore the future collaboration opportunities.

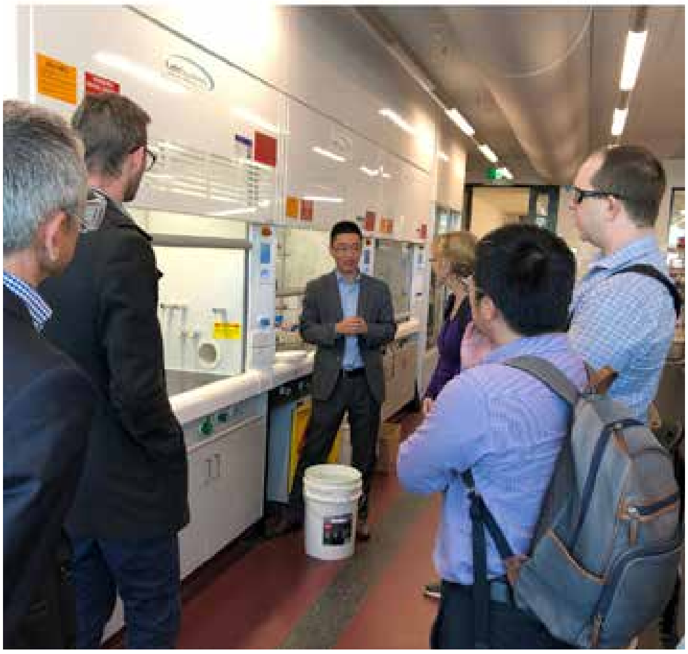
WaterRA brings together experts in industry, government, regulation, consultancy and research to accurately identify, create, manage, share and translate evidence-based solutions to shared problems. It is a leading hub for collaboration and innovation on scientific water issues, WaterRA is an independent, not-for-profit organisation that is member-driven and funded.

Melbourne Water and South East Water Visit

A group of delegates from Melbourne Water and South East Water led by Dr Judy Blackbeard (Melbourne Water) visited the Hub in April. The guests were invited on a tour to the Hub's laboratories in the Green Chemical Futures and Chemical Engineering buildings. Following the laboratories tour, an informative discussion was undertaken with the Hub's director, Professor Xiwang Zhang, examining potential collaboration opportunities.

Melbourne Water is a statutory authority owned by the Victorian Government. It manages and protects Melbourne's major water resources on behalf of the community.

South East Water is one of three Victorian Government owned retail water corporations that provides drinking water, sewerage, trade waste, recycled water and water-saving services for residents and businesses in an area ranging from the south-east of Melbourne to south Gippsland.



Hub Seminars

Click **HERE** to listen to Professor Field online.

Water, Membranes and Water Re-use: Whither this Triptych?, Professor Robert Field

Professor Robert Field (University of Oxford, UK) delivered an insightful seminar on the future of water reuse. His seminar at the Monash Clayton campus in March was attended by more than 40 researchers. Professor Field discussed how the advent of nanomaterials has changed the optimal flux for recycling, water re-use, and future modules and water processes.

Professor Field is Professor of Engineering and Fellow of Balliol College. His research interests include the application of chemical engineering principles to (i) membrane processes with potable and waste water treatment being the main areas of application, (ii) transport phenomena in tissue engineering, and (iii) biofuels and energy analysis, especially well-to-wheel analysis for the evaluation of energy options.

A new paradigm for membrane systems, Professor Michael Tsapatsis

It was our pleasure to meet Professor Michael Tsapatsis from Johns Hopkins University (USA). He delivered an informative and inspired seminar to our researchers and PhD students, sharing his 30 years of research experience in studying metal-organic frameworks (MOF).

Professor Tsapatsis is a Bloomberg Distinguished Professor at Johns Hopkins University. His research interests include reaction engineering, separation and purification processes, nanomaterials, zeolites, and MOFs.

Click **HERE** to listen to Professor Tsatpasis online

Recent developments in polymers of intrinsic microporosity (PIM), Professor Peter Budd

Professor Peter Budd from the University of Manchester (UK) shared his research findings and insights in polymers of intrinsic microporosity in April. Professor Budd is co-inventor of the class of high free volume polymer referred to as PIMs, which is utilised under license from the University of Manchester by 3M.

Click **HERE** to listen to Professor Budd online

Research developments in polymeric membranes for CO_2 separations at Tianjin University, Professor Michael Guiver

We welcomed Professor Michael Guiver to Monash in January. Professor Guiver's research interests include fuel cells, well-defined ionomer membranes, soluble microporous polymers and polymer networks for gaseous separations and gas storage, advanced materials development using functional polymers and novel polymeric architecture.

Click **HERE** to listen to Professor Guiver online

iEESEP2019

The 2nd International Conference on Energy-Efficient Separation
27 - 30 November 2019, Pan Pacific Melbourne Victoria, Australia

CONFERENCE THEMES

- Novel materials for membrane synthesis
- Functional materials for energy-efficient separation
- Mixed-matrix membranes
- Water treatment and desalination
- Wastewater treatment and recycling
- Aerobic and Anaerobic Membrane Bioreactors
- Integrated processes for energy-efficient separation
- New applications of membrane technologies
- Underground water management

KEY DATES

- Abstract Submission Deadline: Extended to 15 September 2019
- Early Bird Registration Deadline:1 August 2019
- ARC-EESep & WaterRA Joint Membrane Workshop: 27 November 2019
- ECR Workshop: 27 November 2019
- Welcome Reception: 27 November 2019
- Full Day Conference: 28 - 29 November 2019
- Conference Dinner: 28 November 2019
- Technical Visit: 30 November 2019

arc-eesep.org/ieesep2019

Membrane Technology for Drinking Water Treatment in Australia Industry , Industry Seminar by Dr Dharma Dharmabalan

Dr Dharmabalan from TasWater presented a seminar on the application and challenges of membrane technology in the water industry. Dr Dhamabalan has worked in the industry in Australia for nearly 30 years and is currently serving at TasWater as General Manager, System Performance and Major Projects.

If you missed the talk, click **HERE** to listen to Dr Dharmabalan online.

UPCOMING EVENTS

ARC-EESep & WaterRA Joint Membrane Workshop, 27 November 2019
(8.30 am - 1.30 pm, Pan Pacific Melbourne)

ECR Workshop (Preparing for a Post PhD Career), 27 November 2019
(1.30 - 6.00 pm, Pan Pacific Melbourne)

iEESEP2019, 27 - 30 November 2019
Pan Pacific Melbourne

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