APRIL 2021

RIE NEWS

SG GUIDE TO TECHNOLOGY, INNOVATION & ENTERPRISE

SPECIAL

FIGHTING CLIMATE CHANGE THROUGH SCIENCE & TECH

COMMENTARY

THE SEA-LEVEL RISE EMERGENCY

FEATURE

NEW BATTERIES USING ORANGE PEELS

Q&A

COOLING DOWN SINGAPORE

CONTENTS

OVERCOMING CLIMATE CHANGE THROUGH SCIENCE & TECH

Research projects, and innovations that will help prepare Singapore for the impact of climate change.

6

NATIONAL RESEARCH FOUNDATION
PRIME MINISTER'S OFFICE
SINGAPORE

@NRF.Singapore @NRFsg @NRFsg

RIE NEWS is a publication of the National Research Foundation Singapore, Prime Minister's Office.

Please send story pitches, ideas, and suggestions to communications@nrf.gov.sg

Images: NUS, NTU

RESEARCH ROUNDUP

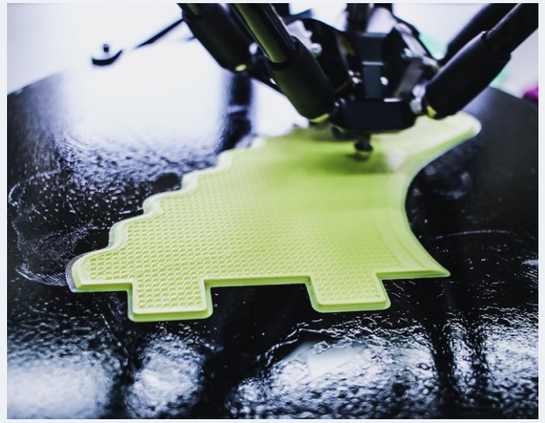
IDENTIFYING VEGGIE MICROBES

A team of researchers from the National University of Singapore (NUS) has identified almost 300 species of micro-organisms that grow together with common Asian vegetables. This is the first step towards helping high-tech urban farmers produce more crops with less chemical fertilisers. Currently, what little is known in this field of research has been obtained mostly from standard plant species used in experiments, and they are non-vegetables. Collaborating with a commercial urban farm in Singapore, the research team sought to close this gap, which will address food and nutritional security and cater to both quantity and quality aspects of food production. Building upon their research, the team will be conducting detailed studies to identify the best microbial strains for enhancing crop production.

3D PRINTING FOOD

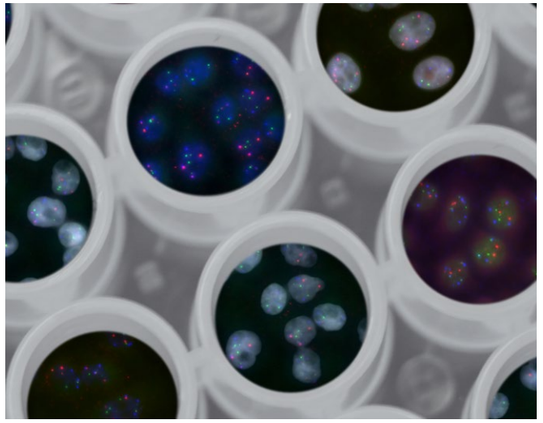
Researchers from Nanyang Technological University, Singapore (NTU), Singapore University of Technology and Design (SUTD) and Khoo Teck Puat Hospital have developed a new way to create "food inks" from fresh and frozen vegetables, that preserves their nutrition and flavour better than existing methods. Not only does this technique preserve the nutrition of the printed food, it also made it more palatable. This new method of making food inks should lead to increased meal consumption by patients, contributing positively to their physical health and mental state of mind.

4D PRINTED SHAPE MEMORY POLYMERS



SUTD researchers and their research collaborators have successfully demonstrated the four-dimensional (4D) printing of shape memory polymers in submicron dimensions, which are comparable to the wavelength of visible light. This has allowed the researchers to explore new applications in the field of nanophotonics. The 4D printing technology allows 3D printed structures to change their configurations over time and is used in a wide variety of fields such as soft robotics, flexible electronics, and medical devices. The researchers said that the 3D printed nanostructures are able to recover their shapes and structural colour after they've been mechanically flattened into a colourless, transparent state.

CORRECTING GENETIC MUTATIONS



A team of researchers from the Agency for Science, Technology and Research's (A*STAR) Genome Institute of Singapore (GIS) have developed a CRISPR-based gene editor, C-to-G Base Editor (CGBE), to correct mutations that cause genetic disorders. The CGBE editor advances the widely adopted CRISPR-Cas9 technology to enable molecular surgery on the human genome. Researchers said that this new technique could potentially open treatment options for approximately 40 percent of the single-base substitutions that are associated with human diseases such as cystic fibrosis, cardiovascular diseases, musculoskeletal diseases, and neurological disorders.

Homeowners, especially those staying in noisy districts, can look forward to improved living comfort with an invention by researchers from NUS that reduces outdoor noise and improves indoor ventilation. Dubbed the Acoustic Friendly Ventilation Window, this system cuts environment noise levels by 26 decibels, which is roughly more than a fourfold reduction in terms of a human's perception of loudness. While keeping the noise out, the device is also able to provide four times better ventilation by allowing air to pass through a staggered vent at the bottom of the window and out through another staggered vent at the top. A dust particle filter, like those used in air-conditioning units, can also be added to the system to filter dust particles or pollutants.

A BREATH OF FRESH AIR FOR NOISY PLACES

Images: NUS, NTU

Whizz Mobility, a student start-up at NTU, has developed a fleet of self-driving robots that deliver in a smarter, greener and contactless manner, making it a safe option in a pandemic. Dubbed the FoodBot, these four-wheeled electronically powered robots have delivered over 6,000 lunch and dinner orders on the NTU campus since June 2020 – when Singapore started Phase 1 of its exit from the circuit breaker. Each FoodBot is designed to carry a 50kg load. It travels at a safe speed of 5km/h – the average human pedestrian walking speed – on pre-mapped delivery routes. Its onboard cameras and algorithms developed by the students help it to navigate around people and objects. Whizz is now in talks with food and beverage partners on potential collaborations and is exploring the option of extending its delivery services to non-food partners.

ROBOT FOOD SERVICE

SPECIAL

OVERCOMING CLIMATE CHANGE THROUGH SCIENCE & TECH

Singapore's **Research, Innovation and Enterprise (RIE)** investments have contributed to helping the nation overcome its resource constraints, while improving overall liveability and sustainability.

In particular, the **Urban Solutions and Sustainability (USS)** domain under the RIE 2025 plan will further strengthen Singapore's capabilities in building a liveable, resilient, sustainable and economically vibrant city.

In this special segment, we will explore some of the projects under the USS domain that will prepare Singapore for the impact of climate change.

This includes supporting **climate science** research that deepens Singapore's understanding of climate change impact, such as in sea level rise and changing weather patterns.

The USS domain will look into developing solutions that enhance national **adaptability** and resilience to the impact of climate change. It will also foster innovations that help the nation **mitigate** the effects of climate change.

SPECIAL // CLIMATE SCIENCE

THE SEA-LEVEL RISE EMERGENCY

With over 25 years of research experience in the field, **Professor Benjamin Horton**, Director of the Earth Observatory of Singapore and Professor at the Asian School of the Environment at NTU, pens his thoughts on the rising sea levels, and why this is an important issue for Singapore and beyond.

> **"The sea level is rising primarily because global temperatures are increasing, causing ocean water to expand and land ice to melt.**
>
> Professor Benjamin Horton
> Director of EOS, NTU

There is increasing awareness of the looming impact of climate change on the environment and human life as we know it.

One key focus is rising sea levels, an area of research I have been engaged in for 25 years. Rising seas increase the vulnerability of cities and the associated infrastructure that line many coastlines around the world because of flooding, coastal erosion, degradation of coastal habitats and salinisation of surface and ground waters.

My research has shown that global sea level rose faster in the 20th century than at any time in the past three millennia, and observations and projections suggest that it will rise at a higher rate during the 21st century and beyond.

Future sea-level rise will generate hazards for coastal populations, economies, and infrastructure of Southeast Asia, which has over 400 million people living in low-elevation coastal zones.

The sea level is rising primarily because global temperatures are increasing, causing ocean water to expand and land ice to melt. About a third of its current rise comes from thermal expansion — when water grows in volume as it warms. The rest comes from the melting of ice on land.

In the 20th century the melting has been mostly limited to mountain glaciers, but the big concern for the future is the melting of giant ice sheets in Greenland and Antarctica. If all the ice in Greenland melted, it would raise global sea levels by seven metres.

Antarctica is twice the size of Australia, two to three kilometres thick, and has enough water to raise sea levels by 65 metres. That is more than a third of the height of the Singapore flyer and seven times the height of the Merlion statue. If a few per cent of the Antarctic ice sheet were to melt, it would cause devastating impacts.

Satellite-based measurements of the Greenland and Antarctic ice sheets show that this melting is accelerating. Greenland is now the biggest contributor to global sea-level rise. Greenland went from dumping only about 51 billion tonnes of ice into the ocean between 1980 and 1990, to losing 286 billion tonnes between 2010 and 2018.

That is a staggering 76 trillion gallons of water added to the ocean each year, which is equivalent to 114 million Olympic-size swimming pools. Not too long ago in 2019, Greenland had set a new record for ice loss, shedding approximately 532 billion tons!

Singapore is a hot spot for sea-level rise

Most people are surprised to learn that, just as the surface of the Earth is not flat, the surface of the ocean is not flat, and that the amount of sea-level rise will vary from place to place.

Regional sea-level trends include land subsidence or uplift due to geological processes, the strength of ocean currents and gravity.

The relative influence of these regional factors determines whether rates of local sea-level change are higher or lower than the global average, and by how much.

One of these hotspots is Singapore. As Greenland and Antarctica are so large, they exert a significant gravitational pull on water, which means that all the water on the planet is drawn towards the poles.

As the ice melts, however, the force of this pull to the poles weakens. This means more water is drawn to the equator instead.

When ice caps melt, countries such as Singapore that sit almost along the equator, will get much more than its regular share of water – roughly about 30 percent more.

Sea-level science

Understanding the physical processes driving global and regional changes is key to predicting the impact of rising seas and extreme events. But future projections of sea-level rise in Southeast Asia are poorly constrained, because of limitations in tide gauge observations and proxy reconstructions.

The spatial coverage of tide gauges is patchy, fewer than 50 years in length and many records are 'contaminated' by inadequately understood vertical land motion. Proxy reconstructions of sea level on multi-decadal to millennial scales are restricted to one location in Southeast Asia, further precluding the assessment of regional driving processes.

Coastal cities such as Singapore, especially, need to invest in the science of sea-level rise – by funding institutions, scientists, and research programmes. This is the only way its leaders can possess the environmental intelligence and data they need to plan and take measures to meet the challenge of sea-level rise.

Besides the increase in sea levels, the trend towards more frequent extreme climate events, such as droughts, wildfires, heavier rains and storms, underscores how important it is for cities to enhance their understanding of and ability to predict and manage climate change.

Singapore needs a comprehensive and integrative climate change research and development program, one that not only contributes to our fundamental understanding of climate change but also informs and expands Singapore's climate choices.

EARTH OBSERVATORY OF SINGAPORE

The **Earth Observatory of Singapore** conducts fundamental research on earthquakes, volcanic eruptions, tsunamis and climate change in and around Southeast Asia, toward safer and more sustainable societies.

It has identified **five specific research objectives** to meet the challenges of the sea-level rise emergency, which are led by an expert in the respective fields.

Associate Professor Emma Hill: Solid Earth contributions to sea-level change, including modelling of tectonic effects and/or linking of land-height and sea-surface changes using Global Navigation Satellite System Interferometric Reflectometry, satellite altimetry, and other geodetic datasets.

Assistant Professor Aron Meltzner: Past sea-level change, in particular, reconstructing changes in sea level and land level at multiple time scales using geological proxy data such as corals and mangroves.

Associate Professor Adam Switzer: Extreme sea levels, including the modelling of tides, storm surges and river flooding in coastal environments and geospatial analysis in coastal areas.

Professor Benjamin Horton: Determining the rates, mechanisms, and geographic variability of sea-level change to produce robust and dynamic local projections of rising sea levels.

Assistant Professor David Lallemant: Risk-based flood impact projection, especially the multi-scale modelling of exposure, vulnerability and resilience of coastal cities and regions.

SPECIAL // CLIMATE SCIENCE

FROM POLLUTION TO POWER

As efforts to reduce carbon emissions accelerate, A*STAR's **Dr Chen Luwei** and IHI Asia Pacific's **Mr Takuya Hashimoto** discuss their work to convert carbon dioxide into methane.

With companies and countries aiming to cut their carbon footprint to limit climate change, researchers from the Agency for Science, Technology and Research (A*STAR) have developed a better way to help them convert unwanted carbon dioxide into methane, an energy source.

Partnering with Japanese heavy machinery maker IHI Corporation, A*STAR's Institute of Chemical and Engineering Sciences (ICES) has created a novel nickel-based catalyst that converts carbon dioxide and hydrogen into methane, and lasts twice as long as some competitors on the market, saving its users time and money.

Methane is the main component in liquefied natural gas, which is used to generate power in Singapore and other nations.

"City gas providers or factories using natural gas in their facilities can tap on our reactor to generate methane and use it for fuel or power generation," says Mr Takuya Hashimoto, manager of the energy solution group in the Regional Innovation and Solution Centre in IHI Asia Pacific.

The ICES-IHI catalyst's longer-lasting performance is due to its innovative structure. In other conventional catalysts, nickel particles that act as catalysts "sinter" or clump together over time. This reduces the overall number of active sites available to convert carbon dioxide into methane.

"The ICES-IHI catalyst has nano nickel particles fixed in place in a porous silica shell, like raisins spread within a muffin. This structure prevents the nickel particles from moving, thus averting sintering," says Dr Chen Luwei, senior scientist in A*STAR's ICES.

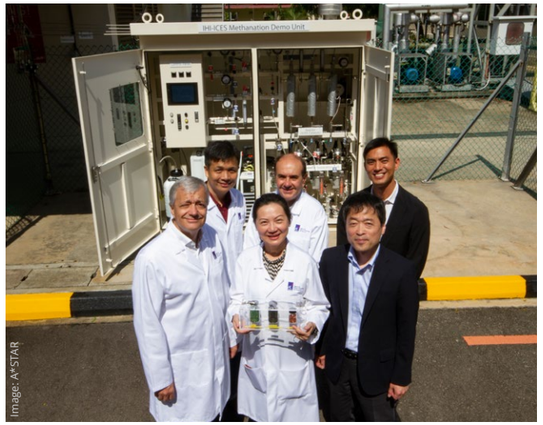
Conventional reactors may also suffer from the build-up of carbon deposits that choke the conversion process. "Such deposition occurs due to the high temperature accumulated in the reactor, so the heat must be removed efficiently," says Mr Hashimoto.

"IHI designed the reactor to achieve this, and we also considered the overall chemical process, including pre- and post-treatments of the system, to avoid such carbon deposition," he adds.

With these improvements, the ICES-IHI catalyst can perform for at least 3,000 hours without any deactivation, which is not possible with other conventional catalysts.

"Furthermore, with our reactor's efficient management of heat, we have reduced the energy needed to produce methane," Mr Hashimoto says.

The team overcame problems in scaling up its core-shell catalyst, and is currently producing yields of 10 kilograms or more by a catalyst manufacturer.



*Researchers from A*STAR and IHI Asia Pacific showcasing their small-scale demonstration unit that converts carbon dioxide into methane.*

IHI has installed a small-scale demonstration unit of the reactor system in ICES's premises on Jurong Island, and a larger one in IHI's Soma IHI Green Energy Centre in Fukushima, Japan. The latter has a capacity of 12 normal cubic metres of methane per hour.

ICES executive director Dr Peter Nagler notes that the collaboration combines ICES's chemical expertise with IHI's engineering prowess to produce an ideal reactor. He says: "It is also in line with A*STAR's aim of translating scientific knowledge to something applicable to industry."

HOT TECH TO KEEP SINGAPORE COOL

The Cooling Singapore project has been working to tackle urban heat, or the urban heat island effect, since it started in 2017. It aims to improve residents' outdoor thermal comfort and well-being, and also to improve Singapore's liveability and sustainability.

Dr Heiko Aydt

Dr Juan Angel Acero

We speak to Cooling Singapore researchers from the Singapore-ETH Centre and the Singapore-MIT Alliance for Research and Technology to find out how the project helps helps keep Singapore, cool. **Dr Heiko Aydt**, computational scientist and lead investigator of the Digital Urban Climate Twin R&D pillar, and **Dr Juan Angel Acero**, climatologist and lead investigator of the Climate and Vegetation pillar, answers our questions.

Cooling SG once announced creating a "digital twin" of Singapore as a model that allows researchers and policymakers to find out factors that affect outdoor temperatures. Could you explain how this works and the progress so far?

Heiko Aydt (HA): If Singapore could manage its urban climate through climate-responsive design, it would help to counter some of the detrimental effects of climate change and urban development on the urban climate, and more importantly, on the residents' thermal comfort and health.

In order to do so, two capabilities are required. First, we need the ability to evaluate how changes in the urban landscape; for example, redevelopment of an existing neighbourhood which would affect the local climatic conditions. This will help planners to better understand the implications – the pros and cons – of alternative planning scenarios.

Second, we need to know how public health, the economy and ecosystem will be affected by changing climatic conditions. Specifically, we want to better understand the risks of rising temperature and the potential benefits of heat mitigation.

The 'Digital Urban Climate Twin' addresses the first need. It allows planners to ask the 'what-if' questions and provides the relevant information required for better-informed urban planning and design to enhance Singapore's climate resilience.

What have you uncovered from the data things that impact temperature in Singapore?

Juan Angel (JA): Through modelling studies based on data shared by the agencies, our initial findings in an earlier phase of Cooling Singapore is that the major contributor to the urban heat is the building mass in Singapore. Buildings alone, without taking into account any indoor activity or air-conditioning (i.e. passive buildings), have a spatial mean impact of 1.8ºC in air temperature on the urban area. Depending on the urban typology and region in Singapore, the impact on air temperature varies, reaching a maximum increase of 3.7ºC in the early morning (averaged values in April). Air-conditioners in buildings are also contributors, although significantly lower than building mass. In the daytime, the impact of air-conditioning on 25 percent of the urban area is more than 0.6ºC in air temperature, reaching up to 1.4ºC in certain areas.

Current data shows that motor vehicles contribute up to 0.9ºC near the source of heat emissions (roads) in the morning period. However, the impact is lower than air-conditioning – only 4.6 percent of the urban areas experience more than 0.4ºC increase in air temperature due to vehicular traffic. Industrial processes, although major contributors of anthropogenic heat in Singapore, have not been fully analysed, and is being studied further. Its impact will be evaluated when the characteristics of the emission sources are available.

HA: In the earlier phase, we also identified a number of knowledge and technology gaps, specifically, the need for climate-sensitive urban design and management capabilities. The development of the Digital Urban Climate Twin is a direct consequence of these findings.

Could you share how you would use such data and modelling to help optimise land use to affect urban heat and improve outdoor thermal comfort? What elements of smart urban design could be incorporated to mitigate heat?

JA: Mitigation of urban heat should be done by

reducing heat accumulation on urban surfaces and promoting the removal of overheated air inside the urban canopy layer; for example, increasing ventilation. In this sense, adjusting the urban geometry of the city, like orientation and width of streets, and specific location of urban elements with respect to the prevailing regional air flow, can mitigate the heat.

Also, new materials and coatings that minimise heat accumulation in urban surfaces, such as roofs, facades, and pavements, are currently available in the market. Finally, the use of vegetation, although already a well-known strategy to beat the urban heat, can be further optimised by understanding how location, combination and type can impact the effectiveness of urban heat mitigation.

The most important thing to consider is that there is no one solution for every urban area and that the same mitigation strategies may not have the same impact in different urban settings. Thus, interventions to mitigate urban heat must be tailored to the specific context where they are applied.

Two types of urban heat sources can be identified – the radiative heat from the sun that is trapped in the urban fabric and anthropogenic heat emitted during human activities in the city such as road traffic. We can avoid the accumulation of heat by, for example, using suitable materials, but also facilitate the dispersion and removal of urban heat generated in the city.

HA: The Digital Urban Climate Twin would provide a better understanding of the urban environment and its local climatic conditions, allowing planners to take an iterative approach in planning. This means that we will be able to iterate over multiple scenarios and their variations in order to better understand the pros and cons. For instance, planners may explore if small plots of urban parks or having larger continuous stretches of greenery would be more beneficial in improving the urban climate.

With air-conditioning becoming a norm for Singaporeans to fight the tropical heat, what ways do you think we can avoid this in terms of a bottom-up versus a top-down approach?

JA: These two approaches are adequate and are in fact necessary. People need to realise that increasing the set temperature of air-conditioners will not necessarily reduce their indoor thermal comfort, but will reduce the anthropogenic heat emitted outdoors. This will benefit the outdoor air temperature and also reduce the building's energy consumption.

Of course, urban design strategies and building morphology and characteristics, such as the orientation of buildings and adequate thermal isolation, should be considered.

Also, buildings could be designed to enhance natural ventilation to improve indoor thermal comfort (in certain conditions) and avoid the extensive use of air-conditioners.

What kind of technologies and capabilities do you think are required to overcome this?

JA: To reduce urban heat, certain emerging technologies could be implemented at a larger scale, or even island wide. For instance, the replacement of all motorised vehicles with electric vehicles could reduce the impact of motorised vehicles on air temperature by about 80 percent. Also, district cooling could be a way of centralising the emission of heat in areas and avoiding the impact of the multitude individual split units.

HA: Considering climate resilience as one of the many parameters of urban planning requires that decision makers understand the risks of rising temperatures, the effectiveness of urban heat mitigation strategies and the implications of their actions. The Digital Urban Climate Twin is being developed to equip decision makers with the necessary technological capability to address these.

The Digital Urban Climate Twin is not a stand-alone technology. Instead, it is a federation of distributed, loosely coupled computational models that represent the different facets of a city, including environmental, land surface, industrial, traffic, building energy, among others. Each of these models requires careful design, development, and validation by the respective domain experts.

Operationalising this digital twin requires cloud computing and high-performance computing resources across multiple organisational domains. Due to its federated nature, there is likely going to be stakeholders across multiple organisations and administrative domains – each hosting, maintaining and operating their respective components, all of which are part of Singapore's Digital Urban Climate Twin.

Do you also believe there's a role for enterprises and start-ups to play in this as well?

HA: Small, hungry and agile start-ups have the ability to disrupt and change the way we do things.

A good example is SpaceX which has radically changed the way the space industry works. The idea of reusable rockets has been laughed at - until SpaceX showed that it is not only possible, but also allows bringing payload into space at a lower cost with potentially increased reliability. 'Flight proven' rockets may turn out to be more reliable than their brand-new throwaway relatives.

Similarly, in the context of the Digital Urban Climate Twin, our ambition is to challenge the way things have been done through innovation. Furthermore, the idea of the Digital Urban Climate Twin is not limited to Singapore. Many other cities in the region and around the globe would be able to benefit from such a technology.

How is Cooling Singapore supporting the nation's efforts to mitigate heat?

JA: We have analysed strategies such as reducing the albedo of urban materials, implementation of electric vehicles in Singapore and expanding district cooling systems in the city. However, the continuous expansion of the urban footprint might not only change the local climate in the specific land parcels, but might also affect the air temperature of the surrounding areas. Therefore, the ongoing conversations with the relevant agencies are important in ensuring that our research is not only relevant to the current situation, but also engages with future developments.

HA: I agree. The Cooling Singapore team is directing its research efforts to help mitigate the urban heat problem faced by Singapore, in close consultation with the Ministry of Sustainability and the Environment, the Urban Redevelopment Authority and other agencies. In addition, heat mitigation involves climate-sensitive urban design, the reduction of anthropogenic heat (which also reduces carbon emissions) and increasing vegetation, among other strategies. These are very much aligned with the Singapore Green Plan 2030. The end goal is the same: to make Singapore more sustainable, liveable and climate-resilient.

KEEPING THE SEA AT BAY

As Singapore faces down the existential challenge of sea-level rise, NTU's **Professor Tan Soon Keat**, a leading expert in water resources and coastal engineering, discusses its options.

How will Singapore keep itself above water, with significant areas of the country at just four metres above the mean sea level or lower, and the sea level continuing to rise due to climate change? The answer may lie in tried and tested engineering feats: seawalls and polders.

Seawalls are coastal defences to keep the sea out, while polders are low-lying tracts of land, below the surrounding sea level, reclaimed by erecting a dyke and then draining the seawater behind the dyke via a network of drains, water pumping stations and water storage spaces.

The Netherlands has a long history of forming polders, and Singapore is currently building its first one, at the north-western tip of Pulau Tekong, with the help of Dutch experts. When the Singapore polder is completed in 2022, it will add 810 hectares of reclaimed land, equivalent to the area of two Toa Payoh towns.

Professor Tan Soon Keat, a leading expert in water resources and coastal engineering who led beach protection works, including rip-rap and breakwater projects that use rocks and other materials to shield shorelines from wave erosion, says that polders would benefit Singapore in several ways.

Image: NTU

Prof Tan Soon Keat conducting an experiment on an underwater structure at his lab.

Prof Tan explains that, "In principle, polders would not require massive quantities of land-fill materials to top up the ground from the original sea bed to the desired platform level, except for the perimeter dykes. One could also implement multiple land uses, including on the dykes, such as roads, train tracks and green belts."

"However, polders also need special drainage arrangements. With Singapore's high rainfall, they would require more energy for mechanical water pumping devices, and dedicated and meticulous operation and maintenance."

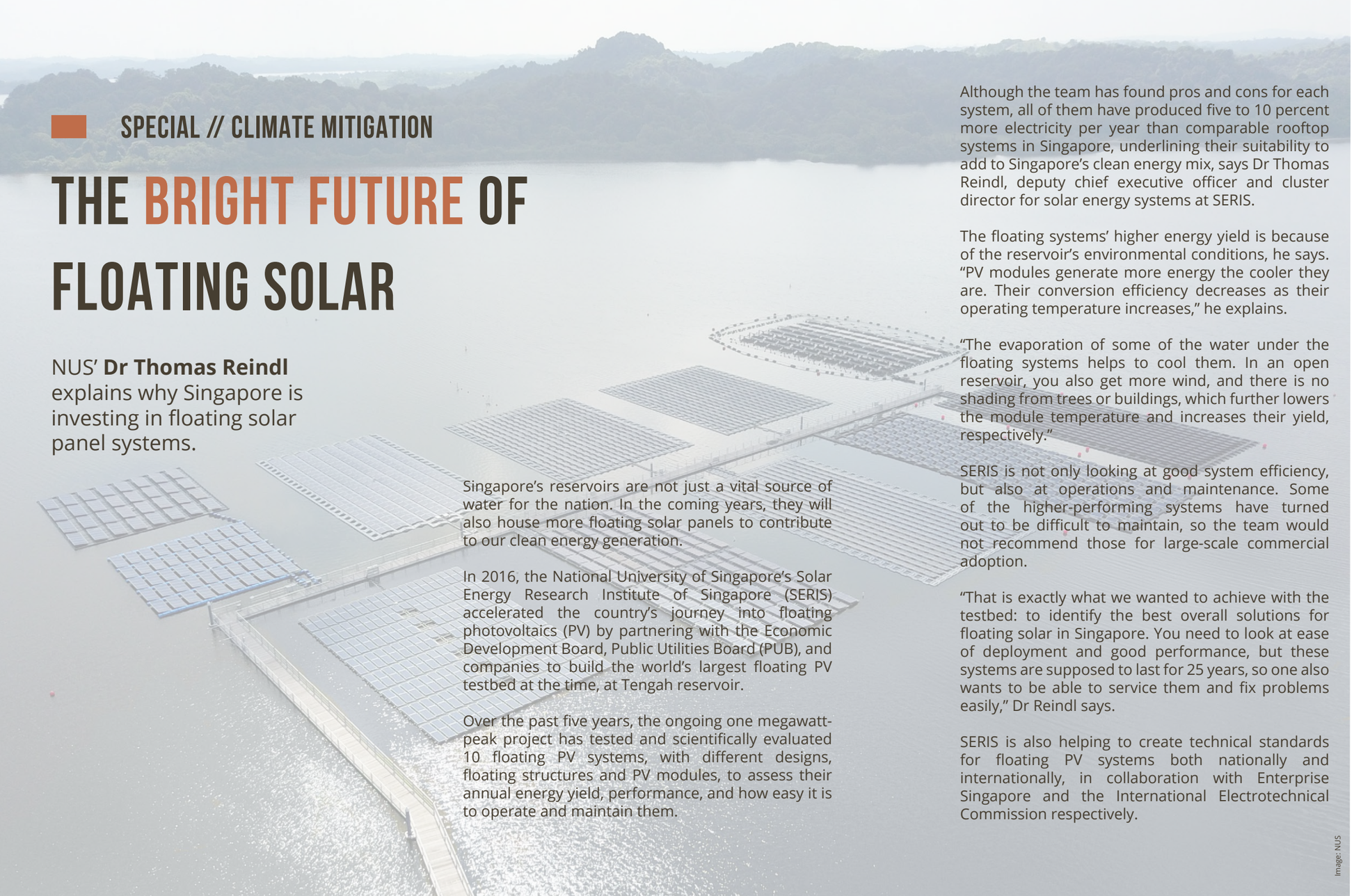
He adds that seawalls could offer Singapore long-term protection: "The land behind the walls could be elevated to a higher platform level well clear of projected sea-level rise. Drainage and other surface flow could be by gravity. Furthermore, although the walls are hard structures, they could be terraced and covered with green features."

Whether Singapore goes for seawalls or polders, the works will require considerable expense. In 2019, Prime Minister Lee Hsien Loong estimated that Singapore will need to spend $100 billion or more in the next 50 to 100 years to prevent the country from going underwater.

As in the Pulau Tekong project, Singapore could learn from other nations' successes. Prof Tan concludes: "For many of the defences, there are well-tested practices, and workable systems with appropriate designs and adaptations for various site conditions."

THE BRIGHT FUTURE OF FLOATING SOLAR

NUS' **Dr Thomas Reindl** explains why Singapore is investing in floating solar panel systems.



Singapore's reservoirs are not just a vital source of water for the nation. In the coming years, they will also house more floating solar panels to contribute to our clean energy generation.

In 2016, the National University of Singapore's Solar Energy Research Institute of Singapore (SERIS) accelerated the country's journey into floating photovoltaics (PV) by partnering with the Economic Development Board, Public Utilities Board (PUB), and companies to build the world's largest floating PV testbed at the time, at Tengah reservoir.

Over the past five years, the ongoing one megawatt-peak project has tested and scientifically evaluated 10 floating PV systems, with different designs, floating structures and PV modules, to assess their annual energy yield, performance, and how easy it is to operate and maintain them.

Although the team has found pros and cons for each system, all of them have produced five to 10 percent more electricity per year than comparable rooftop systems in Singapore, underlining their suitability to add to Singapore's clean energy mix, says Dr Thomas Reindl, deputy chief executive officer and cluster director for solar energy systems at SERIS.

The floating systems' higher energy yield is because of the reservoir's environmental conditions, he says. "PV modules generate more energy the cooler they are. Their conversion efficiency decreases as their operating temperature increases," he explains.

"The evaporation of some of the water under the floating systems helps to cool them. In an open reservoir, you also get more wind, and there is no shading from trees or buildings, which further lowers the module temperature and increases their yield, respectively."

SERIS is not only looking at good system efficiency, but also at operations and maintenance. Some of the higher-performing systems have turned out to be difficult to maintain, so the team would not recommend those for large-scale commercial adoption.

"That is exactly what we wanted to achieve with the testbed: to identify the best overall solutions for floating solar in Singapore. You need to look at ease of deployment and good performance, but these systems are supposed to last for 25 years, so one also wants to be able to service them and fix problems easily," Dr Reindl says.

SERIS is also helping to create technical standards for floating PV systems both nationally and internationally, in collaboration with Enterprise Singapore and the International Electrotechnical Commission respectively.

image: NUS

> **" Singapore has great opportunities for floating PV both on reservoirs and near-shore locations as it seeks to maximise land use and achieve sustainability goals.**
>
> Dr Thomas Reindl
> Deputy CEO, SERIS

This is ever more important as Singapore has already deployed floating PV projects, including in the Lower Seletar and Bedok reservoirs, near-shore floating PV in the Straits of Johor, and is implementing a 60 megawatt-peak floating solar farm in Tengah reservoir. These standards would, for example, detail how to assess the relevant sites' conditions, and how to earth and anchor different systems safely and cost-efficiently.

To share the findings with the global floating solar community, in 2017, SERIS started to organise the International Floating Solar Symposium, an annual conference series dedicated to floating solar, to discuss and solve projects' technical, financing and development issues. Last year, it also launched an International Floating Solar Society to share best practices and speed up the adoption of such systems worldwide.

Dr Reindl highlights that Singapore has great opportunities for floating PV both on reservoirs and near-shore locations as it seeks to maximise land use and achieve sustainability goals: "We have come a long way with floating solar from just a few years ago, not only in Singapore but worldwide. There are now almost three gigawatt-peak of capacity installed globally, and this will only continue to grow at a very fast pace."

AN ENERGY BOOST FOR BUILDINGS

Resync co-founder **Emir Nurov** explains how intelligent energy management systems are bringing buildings to new eco-friendly heights.

Image: Resync

Mr Emir Nurov, Resync's co-founder and managing director, continously strives to develop new energy management technologies for buildings.

Buildings are using more energy as cities expand and people turn to air-conditioners to escape increasingly hot days. Now, Resync, a Singapore-based company that specialises in intelligent energy management systems, is aiming to help buildings deliver comfort and minimise their environmental footprint at the same time.

The company's smart software uses artificial intelligence and machine learning to study and monitor each building's energy sources and usage, to continually optimise both.

"If you have solar panels or other renewable energy assets, it can tap into weather forecasts and historical data to predict how much energy these will generate in the next 15 minutes, one hour, three hours and 24 hours, and adjust the building's energy mix to use more of the clean and cheaper energy," says Mr Emir Nurov, Resync's co-founder and managing director.

"When you have many people leaving an office building for lunch each day, our solution will also sense this, for example through the building's occupancy sensors, and increase the temperature of the air-conditioners to reduce energy consumption," he adds.

"Furthermore, by keeping an eye on the real-time performance of equipment such as solar panels and heating, ventilation, and air-conditioning systems, it can detect abnormalities or degradation that indicate the need for repairs or maintenance. For some equipment, we can go down to the component level to identify exactly what is faulty," he continues.

So far, about 40 buildings in Singapore and Thailand have installed Resync's system, reaping about 10 to 15 percent in energy savings. The firm is fundraising and planning to enter other markets, including Australia.

An SGInnovate portfolio company, Resync also offers solutions for solar and wind power analytics, smart microgrids, Internet of Things device management, smart metering, smart fleet management for electric vehicles, and telecommunications and cell tower management.

Mr Nurov and Dr Jayantika Soni, Resync's other co-founder and assistant director, met when they were both at Entrepreneur First, a London-based accelerator, in 2017. By then, Mr Nurov had worked in the semiconductor industry and REC Solar, a solar power conglomerate, while Dr Soni had developed deep technical expertise in control algorithms for energy systems.

Mr Nurov says, "We knew that energy management was a priority for building owners and managers. We also had a firm grasp of the issues and challenges in the market, and ideas on how to solve them through smart energy management systems. That's why we decided to work together and start Resync in 2017.

"With our solutions, more buildings can take real-time actions so that the comfort level for occupants is the same, but their energy consumption and carbon footprint is reduced to benefit the environment."

HELPING HOTELS GO GREEN

Co-founder of SensorFlow **Saikrishnan Ranganathan** shares how sensors and automation are key to cutting hotels' energy wastage.

Image: SensorFlow

Mr Saikrishnan Ranganathan, Co-founder of SensorFlow, is helping hotels go green by cutting their HVAC's energy use by 20 to 30 percent.

What's the first thing that most people do after they check into a hotel and enter their room? Switch on the air-conditioning to get the room as cool as possible. The problem for the planet, however, is that most people never switch off the air-conditioning until it is time to check out.

"Hotel guests spend less than half of their stay in their rooms, but less than one in 10 switch off the air-conditioning when they venture out," says Mr Saikrishnan Ranganathan, co-founder and chief executive of Singapore-based energy management start-up SensorFlow. The firm gained these insights by studying data from 19 hotels in 2019.

To help hotels minimise their energy use and become more sustainable, SensorFlow offers wireless sensors and big data analytics capabilities to enable them to automate their heating, ventilation and air-conditioning (HVAC) systems.

"With occupancy sensors, for example, we can configure the HVAC system to switch off the air-conditioning in a room, or increase its temperature, if guests are not detected in the room during day time," Mr Saikrishnan says.

"As we collect and analyse data, we can also tell if something is wrong. This can range from unusually high humidity in a room to excessive energy use by an air-conditioner compressor. With this input, hotels can carry out timely servicing and repairs," he continues.

Over 60 hotels in Singapore, Malaysia, Thailand, Vietnam, Indonesia, Cambodia and Hong Kong have installed SensorFlow's solutions and cut their HVAC energy use by 20 to 30 percent. This is about 10 to 20 percent of their total energy use.

An SGInnovate portfolio company, the firm also makes it easier for hotels to tap its solution by taking an agreed-upon portion of their energy savings as its fee, instead of charging an upfront cost.

Looking ahead, SensorFlow is developing other systems, including a smart room allocation programme. This innovation aims to reduce hotels' overall energy use, by assigning guests' bookings to the most energy-efficient rooms available first.

It is also entering new markets, including the Maldives, Philippines, United Kingdom and Europe, and plans to expand to other verticals beyond hotels.

Mr Saikrishnan and Mr Max Pagel, the firm's other co-founder and chief technology officer, believe that their solution will be useful for schools, factories and other spaces.

"When we founded our company in 2016, we decided to focus on hotels because of their high energy wastage, and because our sensors are easy to retrofit with little downtime needed, which works well with the hotel business model," Mr Saikrishnan explains. "Still, we can do more. We will use our systems to help others make sustainable and eco-friendly decisions."

Images: NTU

FEATURE

GIVING OLD BATTERIES A SECOND CHARGE USING FRUIT WASTE

A research team from NTU found a way to upcycle old lithium-ion batteries by using fruit waste – in particular, orange peels.

Professor Madhavi Srinivasan, co-team leader of the research, shares how their innovation tackles two waste streams to power-up new batteries.

When batteries run dry, they always end up in the trash. This also applies to portable devices that use lithium-ion batteries that lose their ability to retain power over time through multiple charging cycles. This is concerning as the demand for lithium-ion batteries have gone up over the years and analysts forecast further industry demand in the future. According to consultancy Cairn Energy Research Advisors, the lithium-ion industry is expected to grow from 100 gigawatt hours (GWh) of annual production in 2017, to almost 800 GWhs in 2027.

There are two issues with this. Firstly, if portable devices or lithium batteries are disposed improperly, they end up in landfills where they decay and leak. As batteries corrode, their chemicals soak into soil and contaminate groundwater and surface water. Secondly, current methods of recycling them produce hazardous toxic gases. While there are other alternative approaches, these still produce secondary pollutants that pose health and safety risks or rely on hydrogen peroxide which is hazardous and unstable.

Scientists from the Nanyang Technological University (NTU) have developed a new method of creating new lithium-ion batteries by using fruit peel waste to extract and reuse precious metals from spent ones. Through a special process, they demonstrated that orange peel waste could be used to not only create functional batteries, but also recover precious metals. The researchers found that a combination of powdered, oven-dried orange peel and citric acid could successfully extract about 90 per cent of cobalt, lithium, nickel, and manganese. This alternative method also tackles two waste streams – food and electronic waste.

Professor Madhavi Srinivasan, co-team leader and co-director of the Singapore-CEA Alliance for Research in Circular Economy (SCARCE) lab at NTU, says, “Current methods of recycling batteries involve incinerating or using strong acids to dissolve them, which in process, produces harmful toxic emissions.

“Our method is cleaner than current industry methods but more importantly, it tackles two waste streams – food and electronic waste – which are key environmental issues that societies face.”

Putting zest into the process

Before oranges are introduced, the ‘green’ method developed by Prof Madhavi and her team involves first shredding and crushing used batteries in a special chamber to form a crushed material known as ‘black mass’. They then extract valuable metals from black mass by dissolving it in a mix of strong acids or weak acids plus other chemicals like hydrogen peroxide under heat, before letting the metals precipitate.

> **“ Our method is cleaner than current industry methods but more importantly, it tackles two waste streams – food and electronic waste – which are key environmental issues that societies face.**
>
> Prof Madhavi Srinivasan,
> Co-Director of the SCARCE Lab at NTU

Prof Madhavi holding up a bag of spent lithium-ion batteries and orange peels on her right, which can be processed together using a special green method to create new batteries.

The researchers then found that the combination of oven-dried orange peel waste, ground into powder and citric acid, a weak organic acid found in citrus fruits, can achieve the same goal. Through experiments, the researchers demonstrated that their approach can successfully extract around 90 per cent of precious materials such as cobalt, lithium, nickel and manganese from the lithium-ion batteries. “Our method was able to extract precious metals which is about the same efficacy to the approach using strong acids, but in a greener and environmentally friendly.

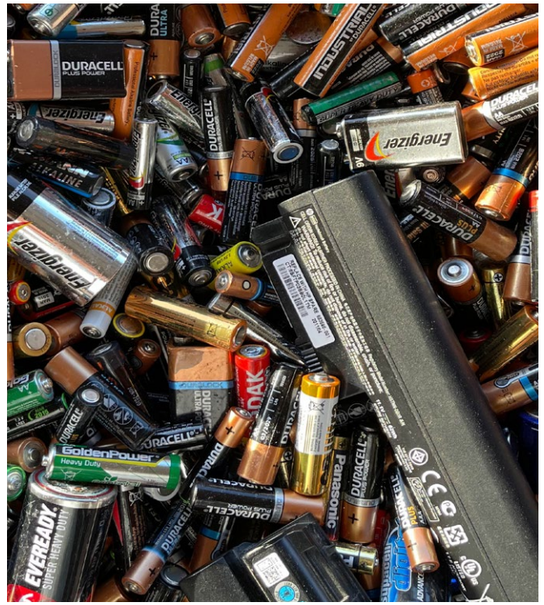
Assistant Professor Dalton Tay, who is part of the research team says, “The key lies in the cellulose found in orange peel, which is converted into sugars under heat during the material extraction process. These sugars enhance the recovery of metals from battery waste.

“Naturally occurring antioxidants found in orange peel, such as flavonoids and phenolic acids, could have contributed to this enhancement as well. Solid residues generated from this process were also found to be non-toxic, suggesting that this method is environmentally sound.”

An a-peeling inspiration

Prof Madhavi points out that she had been researching on batteries for over 14 years, and that it was a natural progression to transition into the recycling methods for them.

She shared that the spark for her current innovation came from buying a S$2 orange juice from a



vending machine. While observing the oranges getting squeezed within the machine, Prof Madhavi wondered if the citric acid from the fruit waste could serve as an alternative source of citric acid. What happened next was history.

She explains: "There are quite a number of these vending machines and it occurred to me that we could capitalise on the sheer amount of fruit waste to help recycle batteries."

Materials science and women in STEM

While the field behind the innovation is a multidisciplinary one, Prof Madhavi points out that at the very core of the innovation, it was materials science. She welcomes young and aspiring scientists to pursue their academic interests in materials science as it offers numerous opportunities to develop innovative and beneficial solutions.

She highlights that, "Materials science is a fantastic field which opens many doors that can contribute and make a difference in a variety of other fields such as biomaterials, polymers, nanoelectronics, energy materials and so on. I persuade young scientists to go for it if they are keen, as I believe that it is a rewarding field that can make a difference to mankind."

A former recipient of the L'Oréal Singapore For Women in Science National Fellowship, Prof Madhavi also encouraged women to pursue their interests in this field, or rather, engineering or STEM in general. "I am delighted that countries like Singapore provide a conducive environment for female researchers to excel," she continues.

"The journey to where I am right now was not easy, but I hope that I can serve as an example that it is definitely not impossible. While hard work and effort is one side of the coin, more changes are needed in academia, to support the development of more young female scientists."

Prof Madhavi, who was also recognised in the 2019 Asia's Top Sustainability Superwoman List of Honour by CSR Works, concludes: "This year, Singapore celebrates the achievements and progress of women, and I encourage young female scientists to ignore the stereotypes and ride the headwinds to fulfil their academic aspirations."

A VIEW ON SCIENCE

200 TRILLION SYNAPSES IN OUR BRAIN

This electron microscope image shows a synapse, the site of communication between two nerve cells.

The circular structures are synaptic vesicles, which are loaded with neurotransmitters that get discharged onto a second neuron which can be seen at the bottom of the image.

The human brain contains more than 200 trillion synapses that form circuits responsible for brain computations and memory storage.

Professor George Augustine and his research team at NTU's Lee Kong Chian School of Medicine, has helped define the molecular workings of synapses and determine what goes wrong with synapses during dementia, schizophrenia, and other brain condisorders.

Image: Lee Kong Chian School of Medicine

NATIONAL RESEARCH FOUNDATION
PRIME MINISTER'S OFFICE
SINGAPORE