Technology Scan

Focus: Technologies for climate resilience

ASIA-PACIFIC

BANGLADESH

Innovative climate smart mapping tool

As a part of the CGIAR research initiative on Asian Mega Delta, the International Rice Research Institute (IRRI), in collaboration with the Center for Environmental and Geographic Information Services (CEGIS) officially launched the Climate-Smart Mapping and Adaptation Planning (CS-MAP). The initiative was launched to enhance food security and climate resilience by empowering stakeholders with actionable insights and location-specific solutions.

This innovative tool integrates scientific research and local expertise to map climate risks, offering tailored adaptation strategies for sustainable farming to address the growing challenges climate change poses to agriculture in Bangladesh's coastal regions. Bangladesh, the seventh most risk-prone country for extreme climatic disasters in the world, faces the growing challenges of climate change. The risks associated with climate change include floods, droughts, salinity, rising sea levels, extreme temperatures, erratic rainfall, and cyclones. These challenges threaten agricultural production, food security, and rural livelihoods.

With changing weather patterns, field-level government officials must implement appropriate agricultural preparations and responsive actions. CS MAP can help them make appropriate and informed decisions. CS-MAP is a participatory mapping approach that has been implemented in 10 districts in the coastal area of Bangladesh, reads a press release.

Working with scientists and experts from BWDB, BRRI, BARI, DAE, and BADC, climate change-related risks in agriculture were identified by assessing the agricultural climate change risks in each area, the extent of each risk was determined, and these risks were mapped into an atlas. During the event launch, these atlases were formally handed over to 10 deputy directors of the Department of Agricultural Extension (DAE). The launch event featured informative presentations on the CS-MAP approach, potential applications, and a video demonstration. Approximately 75 key government officials, researchers, and stakeholders attended the initiative's launch, gaining valuable insights into the innovative tools and strategies developed under the CS-MAP initiative.

https://www.dhakatribune.com

CHINA

Next-generation radiative cooling technology

City University of Hong Kong (CityU-HK) researchers have made a scientific breakthrough in developing next-generation passive radiative cooling technology. Their pioneering work on cooling ceramics, pavements, and textiles helps mitigate heat impacts without additional energy consumption. This innovation has promising application potential in buildings, roads, and clothing, addressing issues such as urban heat islands and greenhouse gas emissions to combat the challenges of climate change.

The team established the start-up i2Cool in 2021 under the incubation of CityUHK's HK Tech 300 programme and developed a cooling paint for roofs and walls. The recent approval of funding from the Hong Kong government's "Research, Academic and Industry Sectors One-plus Scheme" (RAISe+ Scheme) marks a significant step forward in accelerating the commercialisation and application of this groundbreaking innovation. The CityU-HK team plans to establish manufacturing facilities and production lines by the end of 2026.

Space cooling energy consumption has more than tripled since 1990, resulting in a strain on electricity grids, increased greenhouse gas emissions, and the prevalence of urban heat islands. Extreme heat events and record-high temperatures worldwide have left many people around the world vulnerable to heat stress, adversely affecting thermal comfort, labour productivity, and even human health.

To address these challenges, a research team led by Professor Edwin Tso Chi-yan, from CityUHK's School of Energy and Environment, has been focusing on developing passive radiative cooling (PRC) technology. "PRC technology is a universal solution to global warming, as it leverages high solar reflectivity and high mid-infrared emissivity to cool surfaces naturally by reflecting incoming sunlight and emitting thermal radiation to the cold universe, potentially reducing the surface temperature by at least 2°C," explained Professor Tso. "This technology offers an electricity- and refrigerant-free cooling solution, mitigating the heat impact without additional energy consumption."

https://www.cityu.edu.hk

INDIA

Resilient, cost-efficient semiconductors

Researchers from IIT Guwahati, along with IIT Mandi and the Institute of Sensor and Actuator Systems at Technical University Wien have developed a breakthrough technique for growing ultra-wide bandgap semiconductors, IIT Guwahati has said. Named gallium oxide, this semiconductor has the potential to significantly improve the efficiency of power electronics used in high-power applications.

The main advantage of this new technology is that it can withstand extreme

temperatures as high as 200 degrees Celsius. This is ideal for high-power electronics, which are used in a variety of areas such as electric vehicles, high-voltage transmission, traction, and industrial automation.

Power semiconductor devices are the heart of every power electronic system. They are responsible for switching on and off the main supply voltage, and this can cause significant losses in terms of efficiency. There is a considerable amount of research into improving the efficiency of power electronic systems by using materials like Gallium Nitride (GaN) and Silicon Carbide (SiC). However, these materials have some limitations, such as high cost.

The new research team has successfully developed superior-quality ultra-wide bandgap compound semiconductors by incorporating gallium oxide with tin. This has improved the conductivity and thermal performance of the material, making it ideal for use in high-power applications.

The findings of the study have been published in multiple research papers in the *Journal of IEEE Transactions on Electron Devices and Thin Solid Films*. The researchers hope that this breakthrough technology will pave the way for the development of more efficient and sustainable power electronics that can support a range of high-power applications.

https://www.msn.com

JAPAN

Turning carbon dioxide into a green fuel

Researchers from Tokyo Metropolitan University have made strides forward in realizing the industrial conversion of bicarbonate solution made from captured carbon to a formate solution, a green fuel. Their new electrochemical cell, with a porous membrane layer in between the electrodes, overcomes major issues suffered in reactive carbon capture (RCC) and achieves performances rivaling energy-hungry gas-fed methods. Processes like theirs directly add value to waste streams and are key to realizing net zero emissions.

Carbon capture technology is a big part of the global strategy to reduce emissions and fight climate change. But the important question of what we do with the captured carbon dioxide remains an open challenge. Do we simply push it underground, or is there more to it? Scientists certainly think so. Using state-of-the-art catalysts and chemical processes, work is underway to try and convert the captured product into something more useful for society.

One particularly enticing application is the conversion of carbon dioxide into an environmentally friendly fuel. Technology has been developed for using electrochemical cells to reduce the carbon dioxide to a formate compound, which itself can be used in formate fuel cells to generate power. However, a significant roadblock is the need for pure carbon dioxide: pressurizing carbon dioxide can be highly energy-intensive. The gas is not converted very efficiently, and the cells do not last very long. Enter reactive carbon capture, where carbon dioxide dissolved in alkaline solutions, like bicarbonate solutions, can be directly used to create formate ions without the losses associated with providing pure gas. The key challenge facing researchers here is the design of a better electrochemical cell that can selectively produce formate ions from bicarbonate ions without losing out to side reactions, like the production of hydrogen.

Now, a team of researchers led by Professor Fumiaki Amano from Tokyo Metropolitan University has created a new cell with excellent selectivity for the conversion of bicarbonate ions into formate ions. In the new cell, electrodes made of catalytic material are separated from a polymer electrolyte membrane by a porous membrane made of cellulose ester. Hydrogen ions produced at one electrode pass through the electrolyte membrane and make it to the porous layer, where they react with bicarbonate ions to efficiently produce carbon dioxide in the pores. The gas is then converted to formate ions at the other electrode, also in contact with the porous membrane. When they put their cell to work, they found that the faradaic efficiency of their cell, the proportion of electrons

converted to formate instead of other compounds, was 85%, even with very high currents. Not only does this outperform existing designs, but the cell was found to operate smoothly for over 30 hours and realize nearly complete conversion of bicarbonate to formate. Once the water has been driven off, all that is left is solid, crystalline formate fuel.

https://www.eurekalert.org

EUROPE

GERMANY

Laser technology for accurate climate monitoring

According to a study published in APL Photonics, scientists at the Max Planck Institute for the Science of Light (MPL) have developed an enhanced laser technology designed to accurately detect and monitor climate pollutants in the atmosphere. A high-power ytterbium thin-disk laser powers an optical parametric oscillator (OPO), which generates steady, high-power pulses in the short-wave infrared (SWIR) spectral band. This enables researchers to detect and analyze a wide range of atmospheric compounds. This innovative technology plays a crucial role in tracking greenhouse gas cycles and understanding the impacts of climate change.

Short-lived pollutants have a notable impact on global warming. Methane, for instance, is especially relevant to the greenhouse effect, as its warming potential is 25 times greater than that of carbon dioxide. However, detecting and monitoring these pollutants is challenging for two main reasons.

Firstly, the absorption spectra of many gases in the conventional infrared wavelengths often used for detection overlap and are interfered with by water vapor. Secondly, because these pollutants are volatile in the atmosphere, they are difficult to trace. The new laser technology overcomes these challenges by focusing on the SWIR band, where pollutants like methane absorb strongly, but water vapor has minimal absorption.

The ytterbium thin-disk laser, which generates high-power, femtosecond pulses at megahertz repetition rates, is central to this breakthrough. This enables the laser to pump an OPO, which transforms pulses into the SWIR region with exceptional intensity and power. The OPO produces steady, adjustable SWIR pulses that are ideal for high-sensitivity spectroscopic applications while operating at twice the repetition rate of the pump laser. Furthermore, the team's innovative approach incorporates broadband, high-frequency modulation of the OPO output, enhancing the signal-to-noise ratio and enabling even more precise detection.

Field-resolved spectroscopy and femtosecond fieldoscopy, techniques that enable researchers to detect and study a wide range of atmospheric compounds with minimal interference, are enhanced by the laser's ability to produce high-power, steady pulses in the SWIR band.

https://www.azooptics.com

Method to boost zinc battery lifespan, energy storage

Researchers at the Technical University of Munich (TUM) have developed a groundbreaking method that significantly extends the lifespan of zinc-ion batteries, potentially enabling them to endure several hundred thousand charge cycles. This advancement, achieved through a specialized protective layer for the zinc anodes, prevents common issues such as zinc dendrite formation, hydrogen generation, and corrosion, which have previously limited battery durability. The protective layer, a porous organic polymer called TpBD-2F, forms a stable, ultra-thin film on the anode, allowing efficient ion flow while keeping water away from the zinc surface.

Lead researcher Da Lei, suggests this innovation positions zinc-ion batteries as a viable, cost-effective, and sustainable alternative to lithium-ion batteries for large-scale energy storage applications tied to renewable sources like solar and wind power. Prof. Roland A. Fischer emphasized the research's sci-

entific impact, noting, "This chemical approach has proven controllable and effective. We believe it has immense potential for scaling up beyond the lab."

This development builds on interdisciplinary work by TUM researchers in chemistry, physics, nanotechnology, and data science, supported by the e-conversion Excellence Cluster. The research, published in Advanced Energy Materials, opens new pathways for engineers to advance production processes for zinc-ion batteries.

https://news.europawire.eu

NORWAY

Large-scale carbon storage

SINTEF researchers are applying methodologies used to transport oil and gas in their efforts to upscale a technology for carbon capture and storage. This is good news for the climate. It now seems that crucial research, conducted by SINTEF and targeted at the oil and gas sector, can also be applied in the battle to mitigate climate change.

The simulation model called Leda-Flow has made it possible for us to understand how we can transport both oil and gas along the same pipeline. This multiphase flow technology has helped the Norwegian oil and gas sector save billions, and the model is now about to be further developed so that we can investigate how CO_2 behaves in similar pipelines.

Technologies involving the capture and storage of CO_2 (abbreviated to CCS) are crucial to the reduction of greenhouse gas emissions to the atmosphere. In the future, we must learn how to handle and store large volumes of CO_2. We must therefore also find out the best ways of transporting the gas and injecting it into huge subsurface reservoirs.

Here in Norway, a great deal of effort is being put into the industrial-scale application of CCS technologies in the oil and gas sector. Among other initiatives, leading sector companies have been utilising the Northern Lights project with the aim of sequestering up to 1.5 million tonnes of CO_2 in subsea

reservoirs during 2024 and a total of five million tonnes by 2026.

At present, there are only very few CO_2 storage projects in operation in Norway, and all are based on the injection of gas derived from a single source and using a single well. The Northern Lights project is aiming to store CO_2 at a much larger scale, involving more complex operations by which gas from multiple sources will be transported and injected using a network of different wells. The CO_2 will be captured from processes such as waste incineration and cement manufacture. This innovation research project has been given the name CO2Flow.

"The project will directly apply the expertise we have accumulated in the field of flow behaviour modelling at the SINTEF Multiphase Flow Laboratory at Tiller outside Trondheim. It will also utilise the knowledge obtained from the oil and gas sector during the development of the LedaFlow model", says SINTEF researcher Ivar Eskerud Smith.

The use of innovative experiments, combined with the development of new data models, will make it possible to predict CO_2 flow behaviour in pipelines. This in turn will enable us to achieve large-scale CCS for application in the oil and gas sector. Results from the data models will help to optimise pipeline design, in particular with a view to the selection of important aspects such as materials and pipe diameter. The results will also contribute towards cost-effective and safe pipeline operation – preventing unwanted occurrences such as unstable flow or low temperatures with the consequent formation of dry ice, which may block the pipelines.

For the most part, the development of the new data models will be carried out at the SINTEF Multiphase Flow Laboratory at Tiller. Additional experiments will be conducted at NTNU's DeFACTO underground testing facility at Gløshaugen in Trondheim. Testing, quality assurance, and commercialisation activities will take place at the offices of the LedaFlow model development partner Kongsberg Digital.

https://www.sintef.no

NORTH AMERICA

USA

Ultra-clean combustion of biofuels

Researchers in the US have developed a method for the efficient combustion of biofuels using a Swirl Burst injector to burn glycerol/methanol blends with near-zero emissions. Detailed in Fuel, the Swirl Burst (SB) injector at Baylor University's Cornerstone Atomization and Combustion Lab (CAC) is claimed to enable ultra-clean combustion for fuels that are typically difficult to burn due to their high viscosity.

According to the Texan University, conventional injectors struggle to burn glycerol – an abundant byproduct of biodiesel production – due to its high viscosity, though it has moderate energy density. In contrast, the SB injector's ability to handle glycerol without requiring costly fuel preheating or processing could transform biofuel economics. The process allows the SB injector to achieve a complete and clean burn by producing fine droplets, significantly reducing emissions of harmful pollutants like carbon monoxide (CO) and nitrogen oxides (NOx).

Lead author Lulin Jiang, Ph.D., principal investigator of the CAC Lab, said this novel technology also enables biodiesel producers to convert glycerol waste into a viable fuel source, promoting a circular economy and reducing the carbon footprint for generating power.

According to the university, the SB injector's flexibility allows the combustion of various glycerol/methanol ratios without hardware modifications, making it ideal for power plants aiming to meet emissions regulations. "Being able to transform waste, such as waste glycerol, into cost-effective renewable energy promotes energy resilience and energy equity for economically disadvantaged groups in a changing climate," Jiang said in a statement.

The research team tested three different fuel blends – 50/50, 60/40, and 70/30 glycerol to methanol ratios by theoretical heat release rate – at multiple atomising air-to-liquid mass ratios

(ALR). All blends are said to achieve over 90 percent combustion efficiency including complete combustion by the 50/50 blend, with near-zero CO and NOx emissions, even in non-preheated, uninsulated combustion setups. This is claimed to be a significant improvement over conventional air-blast or pressure-swirl injectors, which often generate high emissions with high-viscosity fuels.

"The demonstrated high viscosity tolerance and fuel flexibility of the technology signifies that not only waste glycerol, but also the viscous source oils of biodiesel, and other waste-based bio-oils can be directly utilised for energy generation without further processing, significantly reducing biofuel cost and thus potentially stimulating its broad application," said Jiang.

https://www.theengineer.co.uk

Reactor for direct air capture

Rice University researchers have developed an electrochemical reactor that has the potential to drastically reduce energy consumption for direct air capture, the removal of carbon dioxide directly from the atmosphere. The new reactor design could be a part of the solution to the pressing problem of emission impacts on the climate and biosphere by enabling more agile and scalable carbon dioxide mitigation strategies.

A study in *Nature Energy* describes the specialized reactor as having a modular, three-chambered structure with a carefully engineered porous solid electrolyte layer at its core. Haotian Wang, a Rice chemical and biomolecular engineer whose lab has been researching industrial decarbonization and energy conversion and storage solutions, said the work "represents a big milestone in carbon capture from the atmosphere."

"Our research findings present an opportunity to make carbon capture more cost-effective and practically viable across a wide range of industries," said Wang, the corresponding author of the study and associate professor of chemical and biomolecular engineering.

The device has achieved industrially relevant rates of carbon dioxide regeneration from carbon-containing solutions. Its performance metrics, including its long-term stability and adaptability to different cathode and anode reactions, showcase its potential for wide-scale industrial use.

"One of the major draws of this technology is its flexibility," said Wang, explaining that it works with different chemistries and can be used to cogenerate hydrogen. "Hydrogen co-production during direct air capture could translate into dramatically lower capital and operation costs for downstream manufacturing of net-zero fuels or chemicals."

The new technology offers an alternative to the use of high temperatures in direct air capture processes, which often involve running a mixed gas stream through high-pH liquids in order to filter out carbon dioxide, an acidic gas. This first step of the process ties up the carbon and oxygen atoms in the gas molecules to other compounds in the liquid, forming new bonds of varying degrees of strength depending on the type of chemical used to trap the carbon dioxide. The next major step in the process involves retrieving the carbon dioxide from these solutions, which can be done using either heat, chemical reactions, or electrochemical processes.

Zhiwei Fang, a Rice postdoctoral researcher who is a study co-first author, said conventional direct air capture technologies tend to use high-temperature processes to regenerate carbon dioxide from sorbent, or the carbon dioxide-filtering agent. "Our work focused on using electrical energy instead of thermal energy to regenerate carbon dioxide," Fang said, adding that the approach has several additional benefits, including it works at room temperature, needs no additional chemicals, and generates no unwanted byproducts.

The types of chemicals used to trap carbon dioxide have different drawbacks and advantages. Amine-based sorbents are the most widely used, in part because they tend to form weaker bonds which means less energy is required to take the carbon dioxide back out of the solution. However, they are highly toxic and unstable. Even

though basic water-based solutions using sorbents like sodium hydroxide and potassium hydroxide are a greener alternative, they require much higher temperatures to release the carbon dioxide back out.

"Our reactor can efficiently split carbonate and bicarbonate solutions, producing alkaline absorbent in one chamber and high-purity carbon dioxide in a separate chamber," said Wang. "Our innovative approach optimizes electrical inputs to efficiently control ion movement and mass transfer, reducing energy barriers," Wang said he hopes the research will motivate more industries to pursue sustainable processes and fuel the momentum toward a net-zero future. He added that this and other projects in his lab over the years reflect Rice's strategic focus on sustainable energy innovation.

https://www.sciencedaily.com

Technique to help build mangrove resilience

To help combat the loss of these vital ecosystems, researchers from UConn's Global Environmental Remote Sensing (GERS) lab are working to comprehensively monitor the health of mangroves. Their recent study published in Remote Sensing of Environment focuses on mangroves in Florida to see which areas cope with increasingly intense and frequent hurricanes and which mangroves may be at greater risk of being wiped out completely.

Lead author and Postdoctoral Researcher Xiucheng Yang says that thanks to remote sensing technology, decades of mangrove images are available, including images taken after disturbances like hurricanes. "After the disturbance, we can continuously track mangrove conditions, to see what happens due to extreme weather events and the ongoing recovery process of the damaged mangrove," says Yang. "We wondered if we could use this data to predict which mangroves could recover or not."

To see if this was possible, Yang and the GERS team paired a dense Landsat time series with a disturbance detection algorithm they developed previously called DEtection and Character-ization Of the tiDal wEtland change (DECODE). They went a step further and included the element of Recovery and Resilience to automatically monitor mangrove conditions, in a method called DECODER.

The study focused on Florida since those coastlines are home to an estimated 96% of mangroves in the United States. Florida's mangroves are also under growing pressure, with increasingly frequent and powerful hurricanes. Using this method, the researchers mapped mangrove conditions and tracked the trajectories of recovery between the years 2000 to 2022 with an overall accuracy of over 97%.

Department of Natural Resources and the Environment Associate Professor and GERS Lab Director Zhe Zhu explains that monitoring recovery is an important element, as some mangroves recover naturally from disturbances while others decline, and some decline worse than others. By tracking the conditions over time using DECODER, the researchers hope to predict which areas are at greatest risk, to help pinpoint mangroves in need of intervention.

"We can provide critical information to identify hotspots for recovery and restoration efforts," says Yang. "Previously, researchers could only produce a binary map showing mangroves as present or absent. Our dense time series approach goes beyond simple distribution, offering insights into the dynamic health conditions of mangroves, especially their recovery processes following extreme weather events. This capability is unique."

Yang explains that their method differentiates mangrove responses to disturbance, categorizing them as healthy, disturbed, recovering, or declining. "High severity doesn't necessarily mean that a mangrove's recovery ability is compromised. Some highly affected areas can still recover naturally, while others may struggle. That's why we not only assess the immediate severity of events but also estimate the potential and pace of recovery," Yang adds. "For some areas, we indicate that without human intervention, mangroves may either never recover or recover very slowly."

This data is important because it can be used to direct restoration efforts to the areas that need it most. Zhu says that another important question they hope to address is how resilient mangroves are. This use of technology is an example of how humans can work with nature to build resilience in the face of climate change. The GERS lab has plans to apply the DECODER method broadly to aid in mangrove mapping and restoration efforts globally.

https://www.msn.com

AI creates accurate satellite images of flooding

Researchers at MIT have combined climate models with generative AI to create accurate satellite image predictions of areas impacted by flooding. Known as the 'Earth Intelligence Engine', the tool was developed as a visualisation aid to inform the public of the potential effects of impending storms. The MIT team has made the tool available online so that people can see its results in action. The work is published in the journal IEEE Transactions on Geoscience and Remote Sensing.

"The idea is: One day, we could use this before a hurricane, where it provides an additional visualisation layer for the public," said research lead Björn Lütjens, a postdoc in MIT's Department of Earth, Atmospheric and Planetary Sciences. "One of the biggest challenges is encouraging people to evacuate when they are at risk. Maybe this could be another visualisation to help increase that readiness."

Initially, the researchers used AI on its own to create the synthetic images. They applied a generative adversarial network (GAN), a type of machine learning method that can generate realistic images using two competing neural networks. While this model produced realistic images, it also generated 'hallucination' floods at locations where flooding was not currently possible.

"Hallucinations can mislead viewers," said Lütjens. "We were thinking: How can we use these generative AI models in a climate-impact setting, where having trusted data sources is so important?" To overcome this issue, Lütjens

and his colleagues reinforced the AI with segmentation maps of physics-based models that incorporate real, physical parameters such as an approaching hurricane's trajectory, storm surge, and flood patterns. The team was able to demonstrate that the physics-conditioned model outperformed the pure generative AI model.

"We show a tangible way to combine machine learning with physics for a use case that's risk-sensitive, which requires us to analyse the complexity of Earth's systems and project future actions and possible scenarios to keep people out of harm's way," said study co-author Dava Newman, Professor of AeroAstro and director of the MIT Media Lab.

https://www.theengineer.co.uk