The current crop

Technology to produce, convert and store energy is the key to unlocking renewables. These researchers are seeking solutions from many angles.

To meet global energy needs sustainably, countries must combine multiple approaches. These scientists are pursuing breakthroughs in high-profile areas of energy research: hydrogen, grid batteries and electrochemical reduction of carbon dioxide.

Hydrogen power
Anne Lyck Smitshuysen

Anne Lyck Smitshuysen wants to find a cost-effective way to unlock the hydrogen power in water molecules. As a PhD student at the Technical University of Denmark in Kongens Lyngby, she works with solid-oxide electrolysis cells that use electric currents to split water into hydrogen and oxygen.

Lyck Smitshuysen developed a 3D-printed mould to protect the ceramic cells from warping and fracturing during manufacturing, making it possible to increase the cell size from 150 cm² to 1,000 cm². "By upscaling the process, we can make it cheaper to use electrolysis for large-scale applications," she says, estimating that the innovation could reduce the cost of producing hydrogen fuel by 15%.

The research, which was presented at the American Ceramic Society's international conference on advanced ceramics and composites in January, has earned Lyck Smitshuysen a €67,000 (US$68,000) Flemming Bligaard Award for early-career researchers in sustainable energy from the Ramboll Foundation in Denmark. She was also a finalist for the 2022 Future Hydrogen Leader Award from the Sustainable Energy Council, an industry body based in London.

In addition to her PhD research, Lyck Smitshuysen is employed as a fuel-cell specialist at DynElectro, a Danish start-up company focused on hydrogen-based energy. In March, a paper she co-authored described the company's successful attempt to increase the lifespan of hydrolysis cells by rapidly cycling between a direct current and an alternating current (T. L. Skafte *et al. J. Power Sources* **523**, 231040; 2022).

"Right now, it looks like we can prolong the lifetime of these cells from two or three years to at least five," says Lyck Smitshuysen. "Because we are engineers, we won't say that means an infinite lifetime. At some point, something is going to go some way that we didn't predict."

Longer-lasting cells would help to further reduce the costs of hydrolysis, a crucial step towards a greener energy system. "I want to do something to move towards a more carbon-neutral society," Lyck Smitshuysen says. "That's a big motivator." **Chris Woolston**

"Once we take resources from the ground, I want them to contribute to the grid forever."

Storage solutions
Shirley Meng

Shirley Meng sees a future power grid that runs largely on megawatt-scale batteries storing energy harvested from wind and solar power. It's a vision so large that Meng, a materials scientist, felt compelled to leave her lab at the University of California, San Diego, to join the Argonne National Laboratory, outside Chicago, where she is now the chief scientist of the Argonne Collaborative Center for Energy Storage Science. "We needed a national lab to do things on a larger scale," she says.

Large-scale battery power requires nanoscale precision. In a review published in April, Meng and her team describe using artificial intelligence and computed X-ray tomography – a common medical imaging technique – to observe battery function and deterioration in batteries including lithium ion batteries, a type that is often used to support large power grids. (J. Scharf *et al. Nature Nanotechnol.* **17**, 446–459; 2022).

Every bit of wear, no matter how small, erodes a battery's power and longevity. "We're developing tools to enable us to diagnose and quantify battery degradation, so we can come up with engineering solutions to make a battery last for centuries," she says. Whether they are powering cars or entire communities, batteries must be durable and recyclable, Meng says. She wants to get the most out of every lithium atom or any other resource that goes into battery production. "Once we take resources from the ground, I want them to contribute to the grid forever," she says. Increasing the lifespan of a battery also reduces the overall cost per kilowatt hour, a crucial aspect of any reimagining of the world's energy grid.

Although she calls herself a "battery person", Meng emphasizes that it will take a wide variety of energy sources and storage strategies to power the future grid. She envisions a mixture of ion batteries and 'flow batteries', which store energy in liquid tanks. She also sees an important role for hydrogen in energy production and storage.

But batteries will be the foundation, she says. "We have enough solar; we have enough wind. Batteries are the last missing piece for a grid that is stable and sustainable." **Chris Woolston**

Carbon converter
Ying Chuan Tan

Advancing more sustainable sources of energy first motivated Ying Chuan Tan as an undergraduate student in Singapore. Now a chemical and biomolecular engineering researcher at the Institute of Sustainability for Chemicals, Energy and Environment (ISCE2), launched under Singapore's Agency for Science, Technology and Research in March, he is interested in one emerging technology: electrochemical reduction of carbon dioxide.

The process involves using water electrolysis to convert CO_2 directly into ethanol, ethylene and other valuable chemicals – instead of deriving them from fossil fuels. "This helps to make it more sustainable," says Tan. It could also help mitigate the effects of climate change. Capturing CO_2 from the atmosphere and storing it deep underground is expensive. Electrochemical reduction offers a cost-effective alternative, with the added benefits of generating useful multi-carbon products while using renewable energy sources.

But in order for the nascent technology to realize its potential, the carbon conversion efficiency rate needs to be raised to 50% or more, up from the current 30%, says Tan. In 2019, Tan

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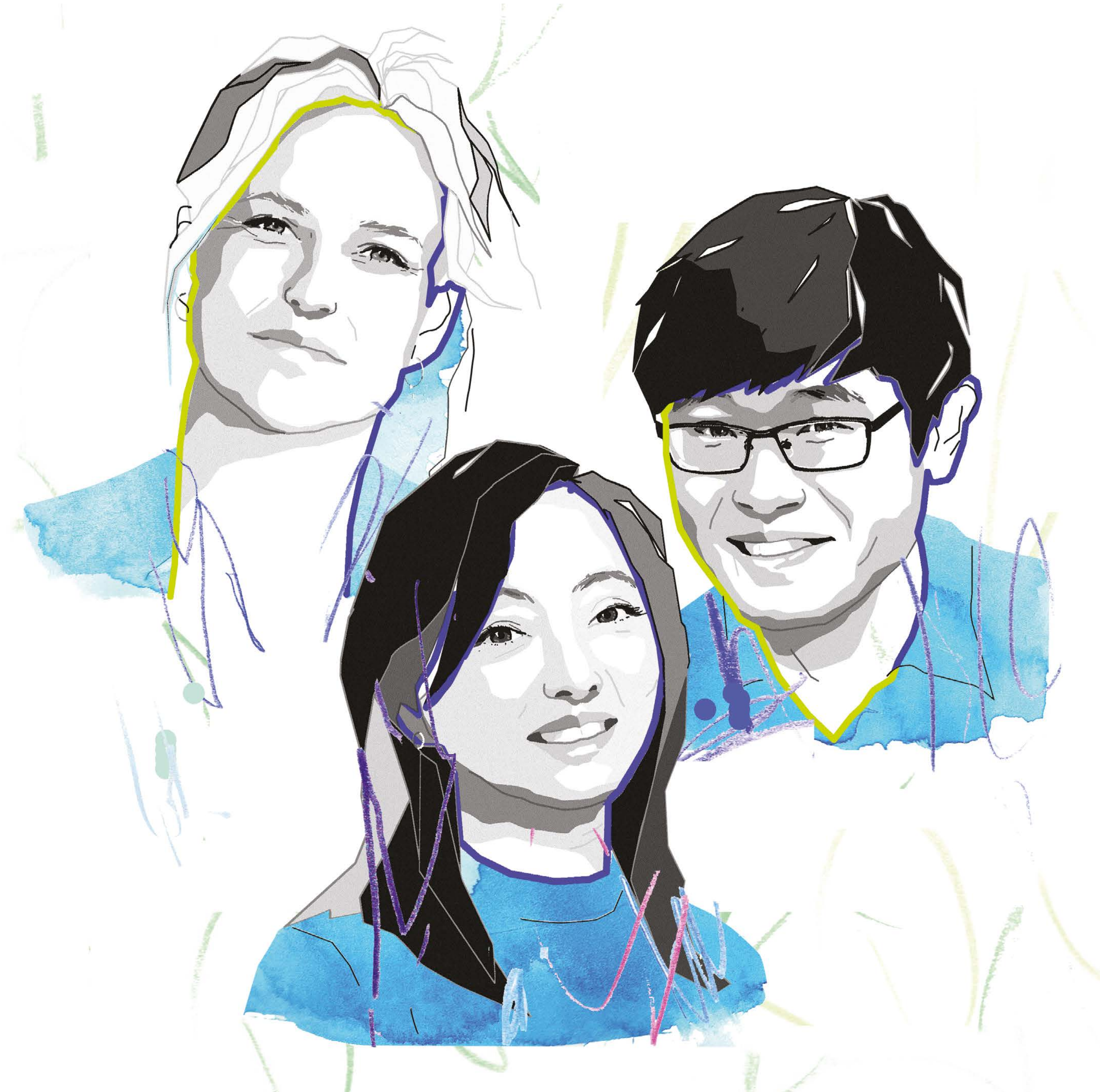

PADDY MILLS

Anne Lyck Smitshuysen, Shirley Meng, and Ying Chuan Tan take multi-faceted approaches to finding energy solutions.

moved to the Korea Advanced Institute of Science and Technology, in Daejeon, to deepen his knowledge of the technology, before returning to Singapore in 2021.

Tan is looking for new catalysts. Silver and gold, for instance, are used to produce carbon monoxide (the main component of synthetic gas), but they are expensive. Nano-sized nickel is a promising alternative, however finding a framework for it to work well on the electrode has been challenging. In 2021,Tan's team described how carbon nanotubes in nickel maximizes the active sites available for binding while facilitating an uninterrupted flow of electrons. This allows CO_2 to be reduced more quickly to carbon monoxide (G. H. Jeong *et al. Chem Eng. J.* **426**, 131063; 2021).

Tan is also studying how varying process parameters ,such as catalyst coating thickness, electrolyte type and the rate of CO_2 flow, can alter conversion efficiency. In 2020, his team discovered that putting more CO_2 into the system doesn't necessarily produce a greater amount of desired multi-carbon products (Y. C. Tan *et al. Joule* **4**, 1104–1120; 2020), contrary to the assumptions of many researchers.

Since Tan moved home, his focus has been on finding ways to support Singapore's chemical industry so that it remains competitive. "I hope my technology can be used globally," he says, "and that we can have more sustainable chemical production through the electrocatalysis route." **Sandy Ong**

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