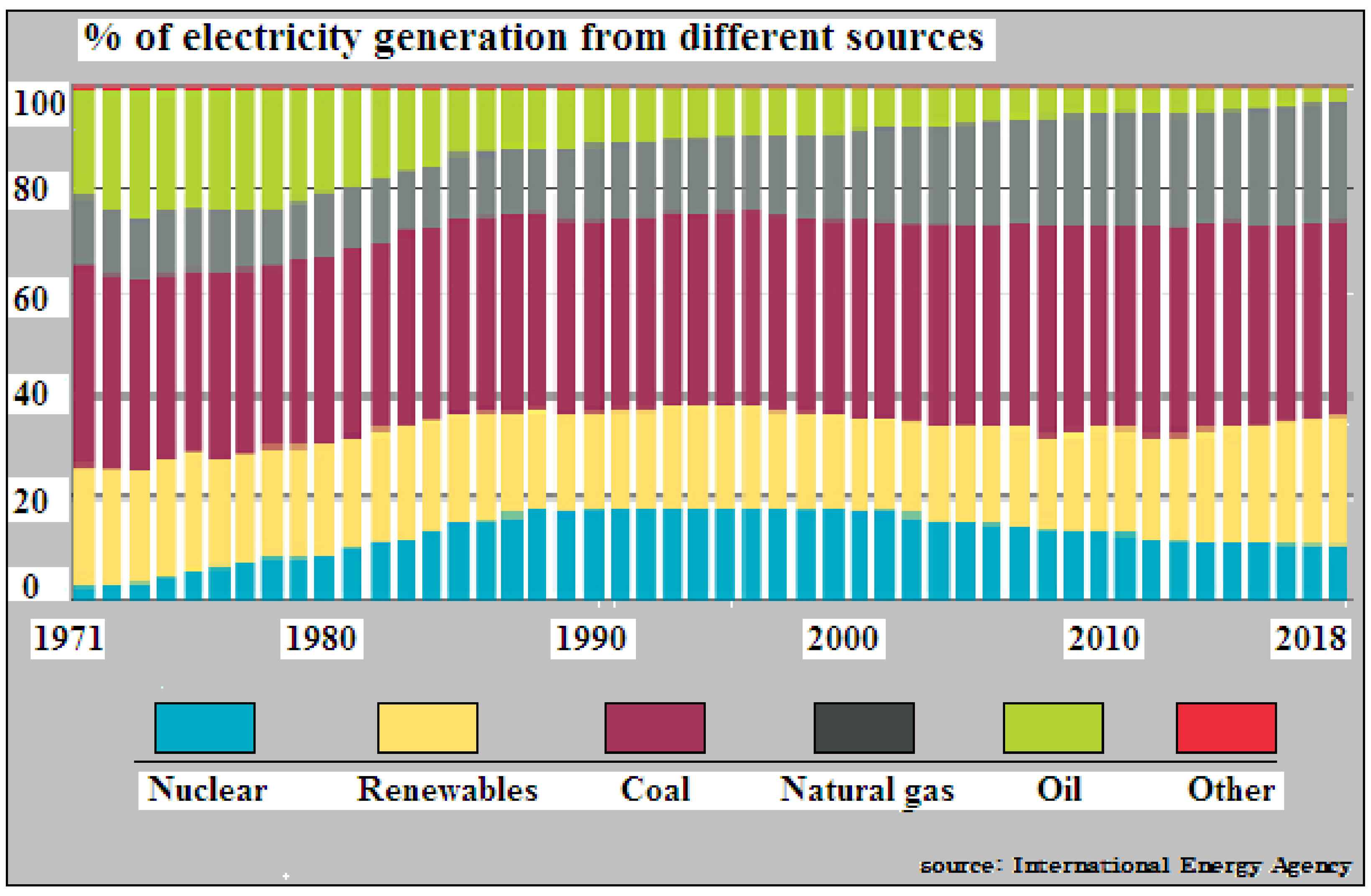
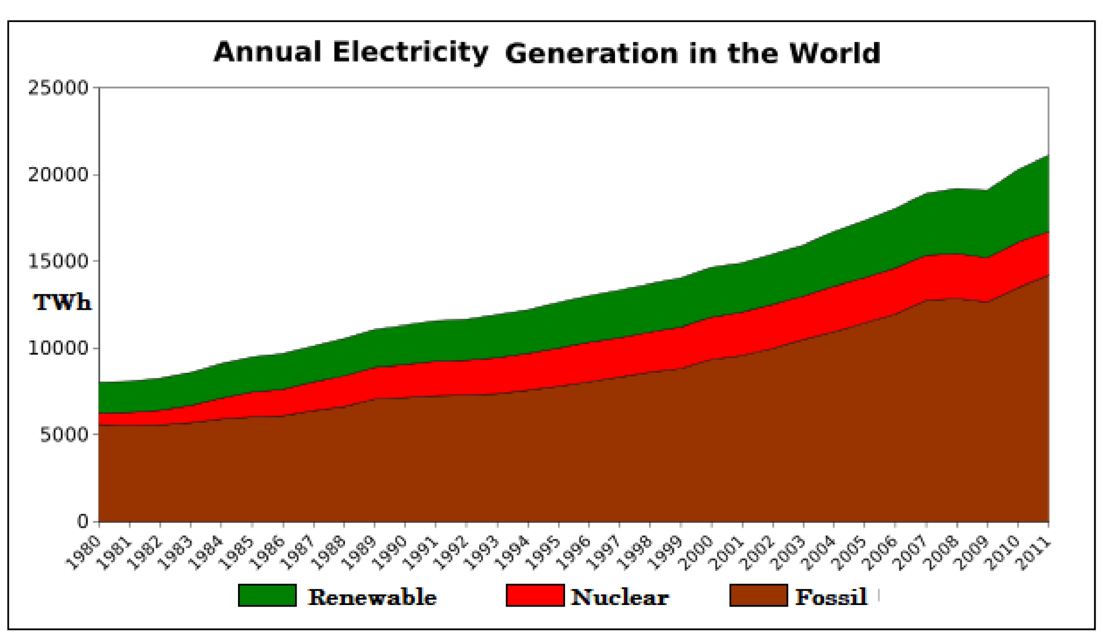
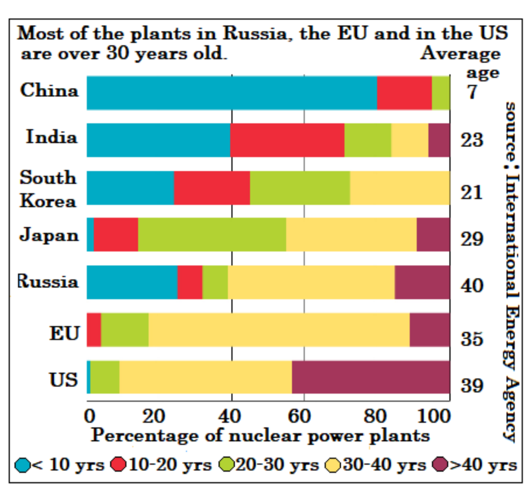
Extend nuclear lifespan

Nuclear power needs a helping hand from governments across the world to stay viable







The onset of the oil crisis in the 1970s gave rise to a spurt in nuclear power installations the world over. These, and the rise of wind and solar power, have held out the promise of winning the race to replace fossil fuels with less carbon intensive sources of electricity.

An article by Washington-based writer, Jeff Johnson in the American Chemical Society journal, *Chemical and Engineering News*, however, draws attention to the slowing growth of these non-fossil based resources and the need for special steps if we wish to drastically reduce our dependence on coal and oil for energy. Johnson cites a study by the International Energy Agency, a Paris-based autonomous intergovernmental organisation, which says the global contribution of nuclear energy, which had touched 18 per cent in the 1990s, may drop to five per cent by the year 2040 if governments do not intervene.

Data reveals that for all the attention paid to renewables and reports of their rising presence, the share of fossil fuels in our energy mix has remained nearly unchanged over half a century. The picture shows a creeping increase in renewables, offset by a reducing share of nuclear power, unchanged use of coal and replacement of oil by natural gas.

The position becomes more alarming when we note that it is not of a stationary power demand that the non-fossil component has stayed unchanged. The rate of consumption has been rising fast, and would rise in the coming decades.

It is evident that reduction in the use of coal, oil and natural gas must come from growth in renewables and nuclear power. Renewables consist of hydroelectric power, wind power and solar power. Hydro plants depend on the siting of rivers and newer plants would involve disturbing populations and ecosystems. Wind power has great scope, but its value is now seen as limited by its own proliferation. And it needs investment and time to set up. Solar panels are now more efficient than before, but large-scale use would consume land area, on which there is growing pressure.

The alternative is hence to promote nuclear power. Not that this does not have its down-side, in terms of radioactive waste generated, the risk of a mishap and again, the considerable cost. However, given the physical limitations of renewables and the obvious need to reduce fossil fuels, nuclear power, with the best measures for disposal of waste and standards of safety, appears to be the only way to go.

It is in this context that we see the nuclear component in the world energy mix down to 10 per cent in 2018, and different factors that stand in its way. An important factor that the IEA points out is that while capacity has been built up, a good portion has now aged and is in need of replacement. Nuclear power makes up 18 per cent of total electricity generation in developed countries. While the US generates 105 GW, out of about 500 GW, from 98 nuclear reactors, France generates 66 GW, 70 per cent of its production, through 58 nuclear reactors. In comparison, India has a total capacity of 385 GW, with 6.8 GW, from 22 nuclear reactors at seven locations.

The IEA reports that in the US, the EU and Russia, most plants are over 35 years old, nearing their design life of 40 years. In the developed world, replacement of aged plants with new ones is almost not an option. Apart from the time it would take, the cost of power from new plants would be much higher than from the existing ones. New plants would hence be unable to compete, and the consequence will be rising use of fossil fuel-based power. While nuclear plants must bear the costs of special measures for waste disposal and safety, the fossil fuel-based industry is spared the cost of the environment harm that it causes.

There are hence only 11 new plants being set up in developed countries — four in South Korea and one each in seven others. There is potential, however, in the developing world, with 11 plants coming up in China (in addition to 46 that it has, with capacity of 46 GW), seven in India, six in Russia, four in the UAE and some others, all state-owned, the IEA says.

As there is yet no model for new plants to be built economically, developed countries have gone for renovating and extending the life of existing plants. The IEA estimates the cost of giving an existing plant another 20 years of life at half to one billion USD, a fraction of the cost of a new plant and about the cost of a comparable wind or solar power farm, and without the delays. In the US, the licenses of all 98 plants in operation have been extended from 40 years to 60 years.

Johnson's article also refers to a paper called "The Nuclear Power Dilemma" by the Union of Concerned Scientists, a 50 year-old group at the Massachusetts Institute of Technology. The paper echoes IEA concerns of adverse economics of nuclear energy and its implications for the drive to contain greenhouse gas emissions.

While the MIT think-tank recommends vigorous state action to implement a system of carbon credits that incentivises reduction of carbon emissions, and to implement standards that impose levels of low carbon emission, it also recommends positive state subsidies to help low carbon technologies compete.

Do we need the power?

While engineers and economists debate ways to generate green power to meet growing demands, another approach is to find ways to limit the energy that we use. This of course, is a tall order, as energy is at the base of our systems of trade and changes that have a material effect may be politically impossible. Belief in the position that there is no alternative to nuclear energy and then, that even this answer has obstacles to surmount, however, could impel the powerful lobbies, like IEA and MIT, which share the belief, to change tack, from finding solutions to the generation problem, to spreading a message of reducing consumption.

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Making climate-ready rice

By reducing the number of stomata that form on rice leaves, it is possible to increase water conservation and drought tolerance in rice

Stomata under microscope

Rice is a global superfood, eaten daily by half of the world's seven billion people. Its impact stretches from the wealthiest in society, who enjoy it with delicacies such as sushi, to the very poorest, who depend on rice for day-to-day survival. Cultivation occurs across six of world's seven continents, with the Food and Agriculture Organisation of the United Nations estimating that, at present, around 510 million metric tonnes of rice are produced annually.

Whilst this level of production is generally meeting the current demand, it's foreseen that for every additional one billion people, an extra 100 million tonnes of rice will be required. This is a huge challenge considering that as many as three billion extra people will populate the earth by 2050, or four billion by 2100.

As well as human population increases, there are a number of other factors that are predicted to put pressure on future rice yields. A critical factor is the availability of fresh water, a key and fundamental resource for rice cultivation. Rice uses water to maintain vigour, acquire nutrients and regulate internal temperatures when it becomes hot. Currently it takes around 2,500 litres of water to produce one kilogram of paddy rice, and this high water consumption contributes globally to rice using between 25 and 33 per cent of all the developed fresh water reserves. These numbers are clearly unsustainable given that water supplies will come under increasing pressure as the human population continues to expand and the demand for rice continues to increase.

This is especially true given that many people will increase the amount of meat and dairy in their diets, both of which are highly water intensive to produce. To put the water-use of rice into context with animal-based foods, it takes six times as much water to produce one kilogram of beef, and twice as much water to produce a kilogram of butter. Clearly, as pressure on water reserves increase, efforts need to be made to improve the efficiency with which rice uses water.

Because of anthropogenic climate change, water supplies for rice cultivation will be tested further by three additional factors. First, changes in precipitation patterns are predicted to lead to more sporadic incidences of rainfall, which in many cases will lead to increased incidences of severe drought.

Second, because temperatures are forecast to rise, rice leaves will release more water to maintain safe temperatures, thereby reducing the amount of water remaining in the soil. And third, because soil water levels will be reduced due to the first two factors, the concentration of salt in the remaining fresh water will increase. This will be further compounded by more frequent influxes of salt water from the rising oceans, again a factor related to past and present human activities.

Such different environmental factors together suggest we need rice varieties, which are more water-use efficient and salt tolerant, yet at the same time permit enough water loss for rice to stay cool when temperatures are high.

Until August 2019, I was a postdoctoral research associate at the University of Sheffield. The project I worked on involved a multi-national team of researchers from the UK, China, Thailand and the Philippines. Using cutting-edge genetic modification and gene editing technologies our groups collaborated to investigate ways to improve the water-use efficiency of rice.

We focused specifically on manipulating microscopic pores called stomata on the rice leaf surface. Stomata serve two main purposes -- first, to enable carbon uptake for photosynthesis, and second, to regulate the release of water. Stomatal regulation over water flow helps to govern the overall water-status of plants, and is crucial for water conservation in the soil and response to drought.

Using GM and GE we generated plants with reduced numbers of stomata per unit area of the leaf. We showed that plants with fewer stomata used less water under normal conditions, resulting in more water being conserved in the soil. This conservation resulted in improved drought tolerance when water was withheld during controlled experiments. We further showed that under higher temperatures plants with fewer stomata could adapt and still regulate plant temperature, yet at the same time survive drought longer than control plants.

Despite the above project coming to a close, we are still working together with one of our partners, the International Rice Research Institute, to undertake field trials using the GM and GE plants we generated together. We hope that our plants will exhibit similarly reduced water usage and improved drought tolerance equivalent to what we have seen during the controlled experiments conducted in Sheffield.

Because our plants take up less water, we have further hypothesised that they might also take up less salt -- therefore being healthier when grown in water with high salinity. We have begun to test whether this is the case under controlled conditions, and preliminary results are looking encouraging.

Given the cultural resistance to GM and GE rice in many rice-growing countries, we acknowledge that our proof-of-concept studies may not be commercialised at this point in time. However, our work clearly shows that by reducing the number of stomata that form on rice leaves, it is possible to increase water conservation and drought tolerance in rice.

My new role job role at The University of Sheffield is a global challenge research fellow. I am now investigating how to optimise rice growth in the future climates of the Mekong Delta in Southern Vietnam. This region has large swathes of land, which already suffer with high salinity and/or drought and this is predicted to worsen with climate change.

At present I'm growing rice varieties from around the world under controlled conditions at the University of Sheffield and am beginning to investigate the stomatal properties associated with the species being grown. I aim to identify rice varieties, which have a natural reduction in the number of stomata.

By early 2020 I will travel to Vietnam to begin working alongside partners at the High Agricultural Technology and Research Institute in the Mekong Delta. We aim to cross varieties identified to have superior stomatal properties with high yielding varieties, thereby generating plants, which will have increased drought and salt tolerance yet still deliver high yield.

The writer is global challenge research fellow, molecular biology and biotechnology, University of Sheffield, UK

How life began

The building blocks of life could have formed in vast, ancient clouds hanging between the stars, according to new research.

One of the basic and essential units of life — known as nucleobases, which help make DNA — have been found by Japanese scientists who simulated the environment of those huge gas clouds. The findings could help us get closer to understanding some of the most fundamental questions about how life on Earth arrived, the researchers say.

"This result could be key to unravelling fundamental questions for humankind, such as what organic compounds existed during the formation of the solar system and how they contributed to the birth of life on Earth," says Yasuhiro Oba of Hokkaido University's Institute of Low Temperature Science.

Researchers have already spotted some of the basic organic molecules that are needed for life, inside of comets and asteroids. They have also been spotted in interstellar molecular clouds, or the vast, gaseous clouds that are strung between stars.

Those molecules are thought to have come down to Earth through meteor impacts, with seeded the key ingredients required to start the beginnings of life. But it is still unclear how they might have formed, a question to which the answer could shed important light on how humanity and all other life on Earth was able to begin.

To conduct the experiment, the researchers used an ultra-high vacuum reaction chamber to create a simulation of the conditions inside of those huge gaseous clouds. They constantly sprinkled a gaseous mixture of water, carbon monoxide, ammonia, and methanol onto a material made to simulate cosmic dust, which was cooled down to -263oC, and then hit with lamps that could kick off chemical reactions.

Out of that machine came an icy film that gathered on the simulation of the dust that was inside the chamber. When researchers warmed that up and then analysed it, they found those nucleobases that are required to create DNA and RNA, which are in turn required for life.

They also found other interesting materials, such as amino acids, which make up proteins. "Our findings suggest that the processes we reproduced could lead to the formation of the molecular precursors of life," says Oba in a statement. "The results could improve our understanding of the early stages of chemical evolution in space."

Previous experiments might actually have created those nucleobases, the researchers said, but those conducting them did not have the highly precise measuring techniques to see that they were there.

The Independent

Shrimps' 'hammers'

This image is an X-ray computed tomography scan of a stomatopod, commonly known as a mantis shrimp. Mantis shrimps are aggressive crustaceans that hunt shellfish by cracking open their hard shells using tough, impact-resistant and ultra-fast biological "hammers", which are really their arms, called dactyl clubs.

The mantis shrimp's club-like arms can strike prey at speeds matching those reached by a 5.56mm rifle bullet. The impact can generate a force exceeding 50kg — hundreds of times the shrimp's weight.

Singapore's Nanyang Technological University scientists have been studying the internal structure and mechanical behaviour of these dactyl clubs, with the aim of producing a new class of ceramic materials, which would be resistant to fractures and impact.

The scientists have found that the shrimp's clubs are able to withstand strong blows because they have ceramic-like crystals — called fluorapatite — that move and rotate when struck, absorbing the impact. The different colours in the image highlight varying degrees of calcification, with the shrimp's clubs in red meaning the most calcified, and hence the hardest.

The Straits Times/ANN