MEET THE RESEARCHERS CLEANING UP THE PLANET, ONE GREAT GREEN IDEA AT A TIME. RACHEL SULLIVAN GOES BACK TO THE LAB

SCIENCE CLEANS UP

EXTREME HEAT WAVES. CATASTROPHIC FLOODS. CROP FAILURES. POISONED WATER. GLOBAL PANDEMICS. POLLUTED AIR. MASS EXTINCTIONS. THIS IS NOT A LIST OF BIBLICAL CURSES — INSTEAD IT IS THE FUTURE, IF RISING TEMPERATURES ARE NOT BROUGHT UNDER CONTROL. THAT'S ACCORDING TO SEPARATE REPORTS BY THE WORLD BANK, THE ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OR OECD) AND THE INFLUENTIAL CLUB OF ROME.

BIOFUELS ASIDE, ALGAE CAN ALSO BE USED TO PRODUCE HYDROGEN GAS, WHICH CAN THEN BE USED AS FUEL. SOME RESEARCHERS HAVE EVEN DESIGNED BIOREACTORS SPECIALLY FOR THIS PURPOSE

PHOTO: GETTY IMAGES

These reports, in addition to others that warn the Artic permafrost is melting unexpectedly fast, freeing breathtaking amounts of greenhouse gases, were released to coincide with November 2012's Doha Climate Change Conference. And indeed, they make for grim reading.

Whether you believe in anthropogenic, or human-induced, climate change or not, as global temperatures rise, all indications are that the world is on a warming trend. Since 1990, the reference year for the Kyoto Protocol, greenhouse gas emissions have already increased by 54 percent — and 2012 has been labelled the ninth hottest year on record. Human civilisation evolved in a more moderate climate, meaning that likely temperature rises of between 4.2 and five degrees Celsius will cause life as we know it to change. We can expect more extreme weather events, such as prolonged droughts, intense storm systems such as Superstorm Sandy, and the disappearance of low-lying areas — as well as the structures and people that call them home — thanks to rising seas and coastal erosion.

Despite growing awareness of the impact of our energy consumption, global energy demands are set to increase by 53 percent by 2035 (using 2008 figures as a baseline), led by booming economies in China, India, the Middle East, South America and Africa.

Meeting those demands without cooking ourselves in the process is changing the way we think about energy. While the world has been waking up to the realities of climate change, scientists, researchers, inventors and communities everywhere have been coming up with brilliant ideas, that, while they may not save the planet on their own, could certainly help reduce our impact on it. Here is *Discovery Channel Magazine's* take on some of the most intriguing, out-of-box, or just plain inspired ideas that might help bring our emissions down.

SVARTSENGI POWER STATION IN ICELAND USES GEOTHERMAL ENERGY TO GENERATE ELECTRICITY. AS IT DOES SO, THE PLANT ALSO PRODUCES THE MINERAL-RICH WATERS THAT FEED THE BLUE LAGOON GEOTHERMAL SPA

PHOTOS: GETTY IMAGES

QUOTE UNQUOTE

“*[DEVELOPING ARTIFICIAL PHOTOSYNTHESIS]* IS PERHAPS EVEN MORE IMPORTANT FOR HUMAN HEALTH THAN WAS DECODING THE HUMAN GENOME. IT COULD LOWER GEOPOLITICAL AND MILITARY TENSIONS OVER FOSSIL FUEL, FOOD AND WATER SCARCITY”

DR THOMAS FAUNCE, ORGANISER OF THE TOWARDS GLOBAL ARTIFICIAL PHOTOSYNTHESIS CONFERENCE, AND PROFESSOR AT THE COLLEGE OF MEDICINE, BIOLOGY AND THE ENVIRONMENT, AT THE AUSTRALIAN NATIONAL UNIVERSITY

BLOW, WIND, BLOW

RENEW YOUR ENERGY

Scientists have long sought new ways of converting sunlight into chemical energy — artificial forms of photosynthesis that can store solar energy in liquid or gaseous form. However, a chemical catalyst to make the process work has been elusive. Until now.

With his team, Dr Thomas Meyer, director of the Energy Frontier Research Center in Solar Fuels at the University of North Carolina at Chapel Hill, in the United States, discovered that a catalyst, comprising an atom of the metal ruthenium surrounded by organic molecules, can convert water and carbon dioxide into oxygen, hydrogen and carbon monoxide, in a process similar to natural photosynthesis. The carbon monoxide can then be potentially combined with hydrogen, to make a fuel such as methanol.

In this way, with the catalytic reaction driven by solar energy-powered cells, carbon dioxide could be converted into chemical energy. Eventually, researchers might even be able to modify the ruthenium catalyst to absorb sunlight directly, taking the solar cells out of the equation. “That really would make it like photosynthesis,” Meyer said.

Now that technology is making it possible, monolithic power plants and single-source energy supplies may soon go out of fashion. “There are many innovative technologies that can contribute to addressing climate change and improving sustainability,” says Dr Xuedu Lu, an adviser to the Asian Development Bank’s Regional and Sustainable Development Department. With a background in climate change policy and carbon markets in China, his role is to promote the development and transfer of new and advanced climate technologies to developing countries. He is also involved in promoting the development of an Asian carbon market.

“Although controversial, shale gas extraction (by the process of fracking) can reduce our reliance on coal power and reduce emissions,” he notes. “This is likely to be an important contributor to the changing energy mix, with broad opportunities. Assuming it can be extracted in China.” He adds that carbon capture and storage, mooted as a way of drawing down carbon dioxide from the atmosphere, is not yet a mature technology. “It is a very complicated process. While individual technologies are mature, a whole a lot more development needs to happen before the technology works effectively.”

In the meantime, he says, most of the investment in climate change-abating technologies is in renewable energy development and energy efficiency improvement. “There are many individual technologies contributing to energy saving and technology,” says Lu.

“Wind power is experiencing fast development in China. At the end of 2011, it accounted for 62 gigawatts of electricity-generating capacity.” One gigawatt can power between 700,000 and a million homes. In 2009, research by scientists from Harvard and Tsinghua University even surmised that wind could actually power most of China’s electricity needs from 2030.

While 100 percent renewable energy generation may seem a pipe dream, there is hope. Iceland has already achieved it, for example — 75 percent of its electricity needs are met by hydropower and 25 percent from geothermal energy. In addition, 87 percent of the volcanic country’s demand for hot water and heat is met by pumping steam directly from underground.

Most energy infrastructure is still owned by governments or large corporations, yet there are positive moves towards cooperative ownership by community groups. Hepburn Wind, owner and operator of Australia’s first community-owned wind farm, received the World Wind Energy Award 2012 at the World Wind Energy Conference in Bonn, Germany. Currently Hepburn Wind’s two turbines power only 2,300 homes, yet the wind farm won the international recognition for increasing understanding and acceptance of wind power, in a country largely powered by coal.

Stefan Gsänger, Secretary of the World Wide Energy Association, says that people-owned power is a positive step towards more sustainable energy. “If we want to reach a 100 percent renewable energy supply worldwide with wind energy as a cornerstone, we have to make sure that local communities actively support this endeavour, and benefit from the wind farms in their vicinity. Community power ownership models offer an excellent approach to achieving this objective.”

SWEET SUNSHINE

SOLAR POWER

Not having an obvious instant fix to our renewable energy needs, does not mean we won’t find one, stresses technology futurist and solar enthusiast Michell Zappa, based out of São Paulo, in Brazil. “Think of the internet. Twenty or 30 years ago no one could have predicted how completely it has come to redefine humanity. If anyone had said it would change the way we think about ourselves they would have been ridiculed,” he says.

“Other than the elusive cold fusion, there are no magic bullets that we know of that will fix our current dependence on planet-heating technologies, and if there are, they certainly don’t look like them now,” he notes. “Small incremental changes are more predictable, more palatable in the short term. It is only over time that we can see how they coalesce into the big picture.”

Zappa looks at emerging technologies that have not yet hit the mainstream and how they might be used in the future. He believes better use of solar and nuclear technologies will be a big part of the energy mix in the next two decades. “Almost all of the energy we consume fundamentally derives from the sun, whether directly through photovoltaic devices (that convert sunlight to electricity) or via the more circular route of having been captured by chlorophyll in green leaves, been eaten by dinosaurs, and eventually turned into fossil fuels including coal, oil and natural gas.”

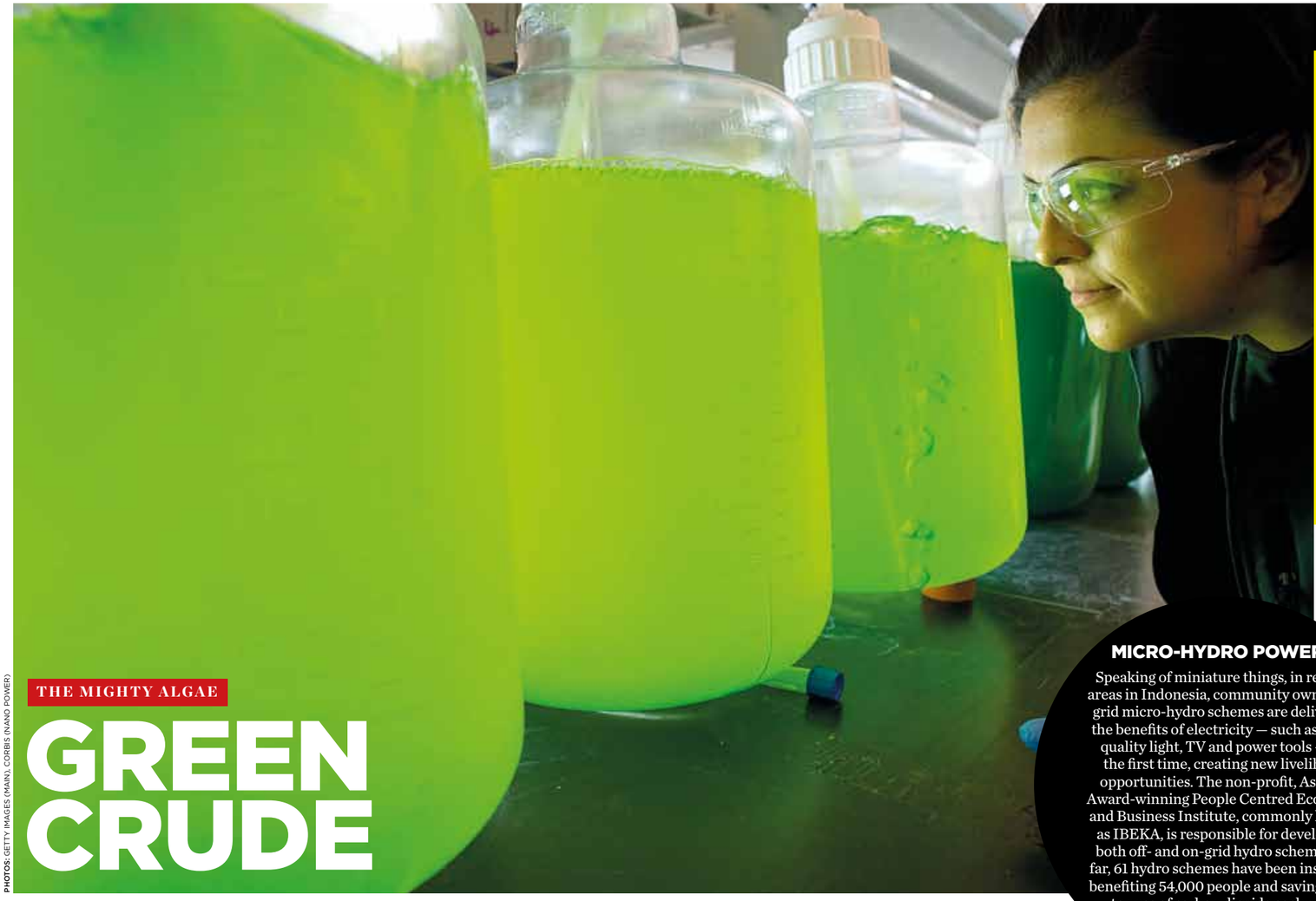
“The optimal way of extracting energy is to find better ways of capturing and storing sunlight,”

he explains. "There is a cost issue however — while there are many exciting developments, solar energy is not quite cost effective just yet. We are able to extract a certain percentage of it, but it is not yet enough to be economically viable." Yet he notes that this problem is being tackled aggressively, and that the situation is changing.

For one thing, there has been a huge increase in demand for solar power, led by countries such as Germany and Japan. In Australia, the country's total installed photovoltaic (PV) capacity in 2001 was 34 megawatt-peaks (MWp, a measurement of the power generated under optimum conditions). By 2011, this had risen to more than 1,400 MWp, which has helped to put a significant dent in the demand for coal-fired power.

Elsewhere, the development of flexible solar cells based on thin plastics is bringing power to remote communities where connection to the grid is not an option. It has also allowed solar cells to be mounted on thatched roofs due to the solar cells' lighter weight, and lent itself to solar-charged batteries that can illuminate a home's interior, providing a safer alternative to kerosene lanterns.

Remarkably, researchers from Vanderbilt University in the United States have combined the photosynthetic protein converting light to energy in spinach (Photosystem 1) with silicon, to create a "biohybrid" PV cell. "This combination produces [electricity] current levels almost 1,000 times higher than we were able to achieve by depositing the protein on various types of metals. It also produces a modest increase in voltage," notes Dr David Cliffel, associate professor of chemistry at Vanderbilt University. "If we can continue on our current trajectory of increasing voltage and current levels, we could reach the range of mature solar conversion technologies in three years." Using this design, the team is now getting down to building a viable solar cell.



PHOTOS: GETTY IMAGES (MAIN); CORBIS (NANO POWER)

THE MIGHTY ALGAE

GREEN CRUDE

The eco-credentials of hydropower have at times been called into question, due to its impacts on local biodiversity and the communities displaced by such schemes. But the power source is here to stay, and the definition of hydropower is likely to broaden with the proliferation of new technologies that can convert wastewater to energy.

Scientists have been trying to make biofuels from algae for decades, and have recently made big advances. However, a 2012 report from the National Research Council of the United States National Academies concluded that in spite of considerable progress, large-scale algae biofuel production still consumes too much water, energy and fertiliser to be sustainable.

Yet despite this, enthusiasts can take heart from new research by NASA scientists, among others. NASA's Offshore Membrane Enclosures for Growing Algae (OMEGA) system consists of large flexible plastic tubes, called photobioreactors. Floating in seawater, the photobioreactors contain fast-growing freshwater algae, cultivated in wastewater. The algae removes nitrates and phosphates from the wastewater, which when in the sea would normally contribute to marine deadzone formation. Then the algae can be put towards producing biofuel that can be used in heavy vehicles.

Unlike other biofuel feedstocks such as corn or sugar cane, which are grown on arable land and compete with food for production space, algae-based biofuels can be grown practically anywhere. In addition, as algae grow, they fix carbon dioxide — which means they take it out of the atmosphere — according to one study, at a rate of 60 tonnes a hectare each year.

We can't rejoice just yet. Algae's drawdown rates still trail well behind our ever-depleting tropical forests, which sequester 300 to 500 tonnes per hectare. The champions, mangrove forests, store more than 1,000 tonnes per hectare across the Indo-Pacific region. Yet with new research revealing that carbon pollution was up to more than 1.1 million kilograms per second in 2011 (a three percent increase on 2010), any drawdown is definitely good news.

A RESEARCHER CHECKS ON BOTTLES OF ALGAE BEING CULTIVATED FOR BIOFUEL RESEARCH AT A SAPPHIRE ENERGY FACILITY IN THE US STATE OF CALIFORNIA. SAPPHIRE ENERGY GROWS ALGAE TO CREATE CRUDE OIL, WHICH CAN BE PROCESSED IN REFINERIES INTO JET FUEL, DIESEL AND GASOLINE

ABOVE RIGHT: CARBON NANOTUBES, ROLLED SHEETS OF CARBON ATOMS THAT FORM CYLINDERS, ARE AN IMPORTANT COMPONENT OF NANOTECHNOLOGY

ALGAE BIOFUELS

GALLONS OF OIL PRODUCED PER ACRE OF CROP PER YEAR, ACCORDING TO NASA

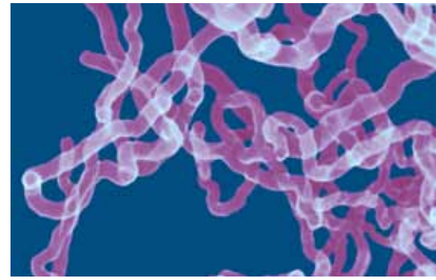
SOYBEAN
50

PALM
600

ALGAE
2,000

MICRO-HYDRO POWER

Speaking of miniature things, in remote areas in Indonesia, community owned off-grid micro-hydro schemes are delivering the benefits of electricity — such as good-quality light, TV and power tools — for the first time, creating new livelihood opportunities. The non-profit, Ashden Award-winning People Centred Economic and Business Institute, commonly known as IBEKA, is responsible for developing both off- and on-grid hydro schemes. So far, 61 hydro schemes have been installed, benefiting 54,000 people and saving 7,400 tonnes of carbon dioxide each year.



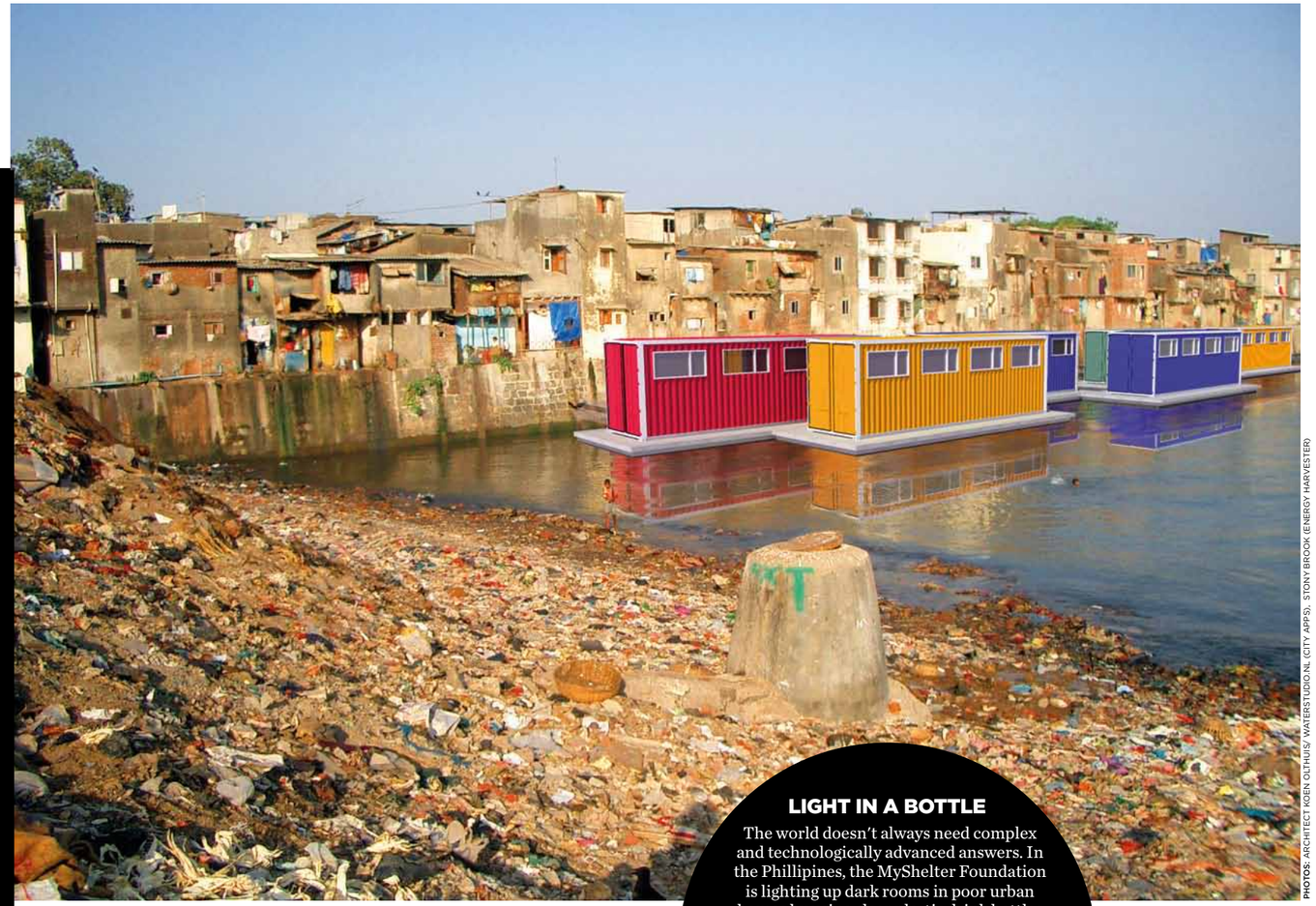
TINY TECHIES

NANOPOWER

While it might have been unthinkable a generation ago, local power generation, where the power supply is embedded within the building and the urban realm, is becoming mainstream, according to Meredith Davey, senior associate director in charge of sustainable and environmental design at Atelier Ten, one of the firms behind the Supertrees *(pictured page 100)* at Singapore's Gardens by the Bay. "Research around nanotechnologies to control pharmaceutical dispersal around the body also has great potential in buildings," he notes. This applies particularly to the manner in which building mass interacts with the space around it, to optimise heating and cooling technologies.

Davey says nanotech is already being incorporated into modern buildings. "In the Netherlands, nanotechnology is being used in windows, not only to control reflectivity and shading but to channel the light energy hitting the glass to the window's edges, where PV cells convert it to usable energy."

Yet no matter how brilliant the ideas and research flooding the market, it all comes to naught if we don't know where it is best applied. "Another major step forward is increasing data awareness. It has become clear how little is known about old buildings and how their operation effects the environment," he says. "Thanks to the information revolution, we can monitor buildings more cheaply, and process larger volumes of data that will help us better understand built forms — and how to optimise and manage them in the future."



PHOTOS: ARCHITECT KOEN OLTHUIS/ WATERSTUDIO.NL (CITY APPS); STONY BROOK (ENERGY HARVESTER)

LIFEBOAT BUILDINGS

CITY APPS FIGHT THE RISING SEAS

As sea levels rise and populations expand in poorer waterside communities, a series of floating structures that provide spaces for food and energy production, shelter and sanitation may help improve the lives of people living in wet slums.

Known as City Apps, Koen Olthius and his team from the Netherlands-based Waterstudio who designed it, recently won the prestigious Architecture and Sea Level Rise Award 2012 from the Jacques Rougerie Foundation, for these flexible and adaptable structures *(pictured)*. The technology, which includes floating PV cell farms, vegetable gardens and other useful structures, was originally designed for wealthy waterside dwellers. It will now be used for communities in need, with the prize money from the award going towards implementing the first City App in the Korail Wet Slum in Dhaka, Bangladesh.

LIGHT IN A BOTTLE

The world doesn't always need complex and technologically advanced answers. In the Phillipines, the MyShelter Foundation is lighting up dark rooms in poor urban homes by using clear plastic drink bottles as skylights. A runner up in the prestigious UK-based Ashden Awards, these ingenious solar bottle lights involve recycled soft drink bottles, water and a few drops of bleach. Sealed into roofs, they enable daylight to filter through. Promoted through social media, the bottle bulbs have attracted global interest and around 25,000 have been installed so far.

CITY APPS ARE ESSENTIALLY FLOATING FUNCTIONS THAT CAN EASILY BE ADDED TO A CITY BY PLACING THEM IN THE WATER WHEN NEEDED

PIEZO-ELECTRICITY

PIEZOELECTRIC SUBSTANCES: CONVERT MECHANICAL ENERGY TO ELECTRICITY

DISCOVERED IN

1880

BY PIERRE AND PAUL-JACQUES CURIE (RESPECTIVELY, HUSBAND AND BROTHER-IN-LAW TO MARIE CURIE, THE PIONEERING RESEARCHER OF RADIOACTIVITY)

PIEZO: FROM THE GREEK WORD *"PIEZEIN"* MEANING "PRESS, SQUEEZE"

2008

SURYA, AN ECO-FRIENDLY CLUB, OPENS IN LONDON. THE DANCE FLOOR IS IMPREGNATED WITH PIEZOELECTRIC MATERIALS AND USE DANCERS' MOVEMENTS TO POWER PARTS OF THE VENUE

EARTH-SHAKER

HARNESSING MOVEMENT

Another area that holds potential for local power generation is piezoelectricity, according to eco-futurist Zappa. "Piezoelectric materials can harvest energy from vibrations, such as the slight motion of a footbridge as pedestrians walk across it, or a car driving across a plate in the road," he says.

While peizoelectricity may not save the world single-handedly, as it involves relatively minor currents and low voltages, the ability to extract ongoing waste and residual energy could have a big consumer impact. "One way to recoup lost capacity is to trickle-charge batteries from waste energy generated from bodies, then use those batteries to power mobile phones and other devices," notes Zappa.

Other potential trickle charge technologies include the movement of artificial leaves on so-called piezotrees that convert wind energy to power. Researchers hope these "power plants" will not only add to the energy mix, but will also blend attractively with and decorate their urban surroundings.

While the piezotree is still in the early stages of development, engineers from Stony Brook University, in the US state of New York, recently won the Best Application of Energy Harvesting award at the Energy Harvesting and Storage USA 2012 conference, for an innovative energy harvester that has the potential to save millions of dollars in energy costs for railroads, while also reducing carbon dioxide emissions.

The Stony Brook team, led by Dr Lei Zuo from the university's department of mechanical engineering, developed a type of energy harvester *(pictured above)* that could save more than US$10 million in trackside power supply costs for railroads in one state alone, along with a reduction of 3,000 tonnes per year of carbon dioxide, and half a million dollars of electricity savings.

"The United States has the longest rail tracks in the world, approximately 140,700 miles (over 226,000 kilometres), which are often in remote areas," Zuo noted in a report. "It is very important but also very costly to power the trackside electrical infrastructure, such as the signal lights, cross gates, track switches and monitoring sensors."

"Our invention, the Mechanical Motion Rectifier (MMR) based Railroad Energy Harvester, can harness 200 watts of electric energy from train-induced track deflections to power the trackside electrical devices," he explained.

Zuo and his team have been working on ways to harvest vibration and thermoelectric energy from various sources for years. In 2011, they were given a prestigious R&D 100 Award — similar to an Oscar in the field of invention — for the development of retrofit energy-harvesting shock absorbers. These absorbers were designed to convert vibration, bumps and motion experienced by the suspension of a vehicle or train, into valuable electric power.

ARCHI-TECH

BUILDING GREENER

Greener methods are also being employed in the often slow-changing field of building technology, one example being the sudden growth in the use of green cement, based on a recipe used by the ancient Romans. With conventional Portland cement consumption on the rise thanks to increasing urbanisation, the extremely energy-intensive material is currently responsible for an estimated five percent of human-produced emissions.

Fortunately, materials scientist Dr Alexander Moseson and his team from Drexel University in the United Kingdom have put forward an alkali-activated green cement featuring limestone and the industrial by-product, slag. While economies of scale still make Portland cement a cheaper option, many governments in Asia are encouraging green building industries, and opening doors for alkali-activated and other green cements. China's newest cement standards reportedly require a 15 percent reduction in energy use — while India's green-building standard emphasises recycling and pollution reduction.

Meredith Davey, who is in charge of sustainable and environmental design at Atelier Ten, specialises in the built environment, but he started out studying quantum physics, before going on to digital art and design, and later became a chartered engineer and environmentalist. He has worked on the design of ecologically sensitive structures for a range of climates and environments.

"One issue is the tremendous lag time between the adoption of a particular technology in every other sector of human endeavour and its integration into the building fabric," he says. "You might throw away an iPod after a couple of years — but a house can stand for centuries. So there is a very conservative approach to designing buildings."

CEMENT AND CONCRETE

800

KILOGRAMS
DURING MANUFACTURING, EACH TONNE OF PORTLAND CEMENT EMITS ROUGHLY 800 KILOS OF CARBON DIOXIDE

5

BILLION
BY 2030, WORLDWIDE CONSUMPTION OF CEMENT IS PREDICTED TO INCREASE TO FIVE BILLION METRIC TONNES, A 43 PERCENT INCREASE FROM IN 2010

126 AD

THE PANTHEON IN ROME, BUILT AROUND 126, STILL BOASTS THE WORLD'S LARGEST NON-REINFORCED CONCRETE DOME TODAY

CHARGE ME UP

CLEANER BATTERIES

It is not only energy generation that will affect our future power story. Creating better batteries to store energy will also be crucial.

"The central obstacle facing sustainable energy is unreliability," explains Dr Manickam Minakashi from Murdoch University's School of Chemical and Mathematical Sciences, in Australia. "Wind turbines don't turn on a still day. Solar doesn't work at night and can be hampered in the day by cloud, dust or snow coverage."

How do we get around that? To provide power at non-generation times, excess energy needs to be stored in batteries, he says. "But storage technologies now being considered, such as molten salt or molten sulphur, work at high temperatures, making them expensive and impractical."

It is a problem they have sought to remedy. Minakashi's team has come up with an interesting new salt-based battery that could hold great potential for affordable, low-temperature storage.

"While the technology is too bulky for portable devices, it has excellent potential for large-scale use, including storing energy from wind turbines and solar farms for later feeding into local electricity grids, as well as use in industry," he notes. The battery also has the added advantage of being based on globally abundant and affordable substances — sodium, iron and manganese. Which could mean putting green energy potential in the hands of the developing world.

A similar storage problem is also hampering the uptake of electric vehicles, which often take hours to recharge instead of just minutes at the gas pump. The UltraBattery, created by Australia's CSIRO, integrates a lead acid battery and a supercapacitor in a single unit cell, harnessing the best of both technologies and producing a battery with high power discharge and charge, and a long, low-cost life. Expected to revolutionise the hybrid car market and make them more attractive to buyers, ultrabatteries can be charged an infinite number of times without degradation, and are very efficient, cost-effective and long-lasting.

For portable technologies, lithium-ion batteries may hold the key to lightweight, affordable rapid-recharge batteries. But there is still a ways to go before these meet expectations. Engineers at the University of California, San Diego, in the United States, recently developed new algorithms that improve the efficiency of existing lithium-ion batteries. This could allow them to be charged twice as fast as is currently possible. However these algorithms need refining and testing before they can be used commercially.

Some people are also looking at other less technological ways of storing energy. Using power to lift a heavy weight converts kinetic energy to potential energy, which is then realised when the weight is allowed to fall. This is the principle behind hydropower, where large volumes of water are stored in a dam, then forced through a narrow outlet to a river below, turning turbines and creating energy in the process. Similar "gravity batteries" have been used to keep pendulum clocks ticking for centuries.

Despite the fact its yield is more efficient than commercial batteries, this method is definitely not at the forefront of technological innovation. "The infrastructure costs for this are high at the moment, and batteries are likely to remain popular because they liberate energy in a predictable manner," says technology futurist Zappa. "But it's a great example of thinking outside the box, to help solve our energy problems."

HYBRID CARS, WHICH USUALLY HAVE BOTH AN INTERNAL COMBUSTION ENGINE AND ONE OR MORE ELECTRIC MOTORS, ARE TOUTED AS A WAY TO REDUCE EMISSIONS

PHOTO: CORBIS

STORING ENERGY

2

BUNNIES
BOTH ENERGIZER AND DURACELL, TWO OF THE BIGGEST BATTERY BRANDS IN THE WORLD, USE RABBITS AS THEIR MASCOTS

1973

LAUNCH OF THE DURACELL BUNNY CAMPAIGN

12,000

HOMES
IN 2012, CHINA ANNOUNCED THE WORLD'S LARGEST BATTERY, WITH SEVERAL LINKED ARRAYS REPORTEDLY TOTALLING THE SIZE OF A FOOTBALL FIELD. IT HAS THE CAPACITY TO POWER 12,000 HOMES FOR AN HOUR

TIDES OF CHANGE

CATCHING WAVES

Tidal energy, which has been used since the 11th century in Britain and France for milling grain, uses the power of water rushing backwards and forwards during twice-daily tides to turn the blades of a turbine and supply energy. Problems with intermittent supply, a common issue with most renewables, has limited its uptake. Yet in areas with large tidal ranges and a nearby population, such as Derby on Australia's Kimberley coast — where tides can reach heights of 11.8 metres — tidal power can provide a vital part of the energy mix.

Wave power is another highly attractive source of renewable energy. Yet while researchers have developed a bewildering array of technologies aimed at harvesting this bio-power source, most struggle to progress beyond the research-and-development stage. One of the few exceptions is Europe's first commercial wave plant, which recently went into service in wave-lashed Mutriku, in northern Spain's Bay of Biscay. It now supplies power to about 600 residents. Since then, similar technology has been used in Scotland and the Azores.

In Australia, a study by the peak science body CSIRO estimated that wave power could supply around 10 percent of the country's energy needs by 2050. Wave power requires large, predictable waves, so it is unlikely to gain much traction in the flatter seas around the equator, or the Mediterranean region. Even on Australia's wave-battered coastline, studies show wave power is only likely to be effective in limited areas, such as on the southern coast, which often enjoys large waves generated by strong Southern Ocean winds.

TIDAL ENERGY

20
PERCENT OF THE UK'S POWER NEEDS COULD BE GENERATED BY TIDAL ENERGY BY 2050

41
NUMBER OF WAVE OR TIDAL ENERGY SITES CURRENTLY IN OPERATION OR UNDER DEVELOPMENT IN THE UNITED KINGDOM

1966
THE YEAR RANCE TIDAL POWER STATION IN FRANCE BECAME OPERATIONAL, THE FIRST IN THE WORLD

500,000
HOMES
THE SHIHWA TIDAL POWER STATION IN SOUTH KOREA, THOUGHT TO BE THE LARGEST IN THE WORLD, PRODUCES ENOUGH ENERGY TO POWER 500,000 HOUSEHOLDS, AND GENERATES 254 MEGAWATTS OF ELECTRICITY PER DAY

UP, UP AND AWAY

VERTICAL FARMING

Look, up in the sky! It's a high-rise orchard. As human settlements sprawl over once-productive farming land, and transporting fresh food over long distances becomes more expensive, smart minds have turned to the idea of high-rise agriculture.

To produce food closer to where it will be consumed, new-look city farms use a combination of hydroponics, nutrient recycling and aquaponics (integrated fish and vegetable production systems). Atelier Ten's Davey, who worked on some of the world's most intriguing vertical gardens, the Supertrees at Singapore's Gardens by the Bay, agrees the Supertrees provide food for thought for those who believe vertical agriculture might hold the answer to supplying locally-produced food to the world's many urbanised populations. Yet he cautions that at present, cost alone would be prohibitive. There are also some key practicalities to consider.

"I'm not sure that vertical gardening is the golden panacea that people think it is — because of the density of planting required per hectare to make producing food cost effective," Davey explains. "Plants also need light to grow, and while solar radiation is strong from many directions in equatorial Singapore, in more temperate climes the influence of shade is much more pronounced."

However, he says that the project has helped to showcase a couple of key advances in building design, including the use of alternate fuels for heating and cooling, as well as integrated processes serving as a driver for building design.

"Gardens by the Bay converts waste heat — generated through the incineration of thousands of tonnes of green waste acquired each year through pruning Singapore's three to four million trees — to chilled air that cools the conservatories," he says. "The ash left over from the waste incineration process is used as high-grade fertiliser in the gardens, in a virtuous, integrated cycle."

PHOTOS: AFP (GARDENS BY THE BAY); THE UNIVERSITY OF SYDNEY (FOG HARVESTING); GETTY IMAGES (WATER DROPLETS)

UP TO 16 STOREYS TALL, THE SUPERTREES AT SINGAPORE'S GARDENS BY THE BAY ARE COVERED WITH OVER 160,00 PLANTS FROM MORE THAN 200 SPECIES — AND THEY LOOK AWESOME WHEN LIT UP TOO

POLLUTION TO FUEL

Urban air pollution is expected to become the biggest cause of premature death by 2050. So it is fortunate researchers may have discovered how to reverse-engineer air pollution, to create fuel. The technology mixes sodium hydroxide with carbon dioxide from the atmosphere, forming sodium carbonate, which is then processed to produce fuel. English firm Air Fuel Synthesis' small refinery produced five litres of petrol in three months, and company executives plan to build a large plant that will produce more than a tonne of petrol daily, plus a large commercial refinery within 15 years.

DRINKING EASIER

HARVESTING FOG WATER

While climate change might be expected to make some areas of the world wetter, others will become drier and subject to more prolonged droughts. The Water for Life Peru project is helping shanty town dwellers without access to drinking water to build inexpensive fog harvesting systems *(pictured)*. The technology has been readily available in wealthy areas for some time — but it has only recently been adapted for use in poor regions. The system collects the small water droplets that make up fog on a mesh screen, until the droplets are heavy enough to trickle down the screen and drip into a storage tank.

"The system is perfect for towns where finances and resources are extremely limited," writes Catherine Goonan, a University of Sydney engineering student involved in the humanitarian project. "No energy is needed to operate the system or transport the water, and maintenance requirements are generally minimal. The simple technique could be life-changing, freeing people from excessive water prices." And could save lives.