# Power from pollution

## CARBON DIOXIDE EMISSIONS OF POWER PLANTS ARE GETTING SET TO BECOME ENERGY SOURCES, SAYS **S ANANTHANARAYANAN**

HVM (Bert) Hamelers, Olivier Schaetzle, JM Paz-García, PM Biesheuvel and CJN Buisman

This is not going to transform power plants from offender to benefactor, but will certainly extract the last bit of energy trapped in the emissions, before they go forth and wreck the environment.

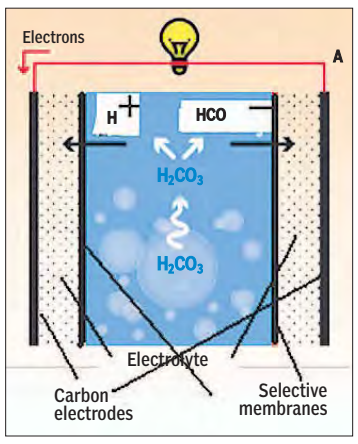
Engineers the world over are devising ways of retrieving the heat left in exhaust fumes or the steam that comes out of turbines. What is being done now is a little beyond using the last heat left in emissions, it is generating electricity directly from the fact that emissions are richer in carbon dioxide than the surrounding air.

HVM (Bert) Hamelers, Olivier Schaetzle, JM Paz-García, PM Biesheuvel and CJN Buisman of Wetsus, Centre of Excellence for Sustainable Water Technology, Leeuwarden, and at Wageningen University, the Netherlands, report in the American Chemical Society's new journal, *Environmental Science and Technology Letters*, an electric cell that gets charged when its plates are exposed alternately to a $CO_2$-rich or normal water medium.

The principle of the method is that liquids or gases that are not mixed, but separate, represent an element of order that has come about by doing work, and mixing the separated materials would dismantle that order and release energy. Out of the total energy that any system contains, either because of physical position or because of orderly arrangement, there is a part that is "available", or can be released by the system going to a state of less *available* energy.

The change in the energy during the transition is written out as a formula, like this: *?G = ?H – T?S*. The symbol "?" means "the change in" and the letters *G*, *H*, *T* and *S* represent the *available energy*, the *total energy*, the *temperature* and the *level of disorder* in the system, respectively. The technical words for G, H and S are *Gibbs "free" energy*, *enthalpy* and *entropy*.

What the equation means is that systems tend to go from a state of high available energy to one of lower available energy in three ways. One is when the total energy falls, like when a ball rolls down a slope, to a lower level. The second way would be when the total disorder of the system increases, or the value of *S*, which has a minus sign, becomes greater. An example of this would be when a volume of gas, which represents the order of being confined to its volume, is allowed to leak out and fill a greater volume. The gas will do just that, as a greater volume is a less ordered state. And the role of *T* in the equation is that changes in the level of disorder have greater effect at higher temperatures.




The change from a state of high to low available energy also represents release of energy, like the higher speed of the ball that has rolled down or the expansion of the gas that fills a larger volume. A practical way of making use of the change in the level of disorder has been in the mixing of liquids, particularly seawater and fresh water. Seawater has concentrated salt in a solution while fresh water has none. The distinction represents order.

Mixing the two should represent disorder and, hence, less available energy. The tendency to mix is exactly what we see — the level of fresh water in coastal wells is well below the sea level. The difference is because the fresh water is impelled to flow into the sea and reduce the level of order in the separation of levels of salinity. The depth of coastal wells shows that the difference can hold up a water column of many tens of metres!

The work that the sun does in lifting water from the sea, through evaporation, and depositing the water on mountains, as snow or rain, can be tapped by hydroelectric plants. And then, the energy of separating the pure and salt water, represented by the lower salinity of river water, can again drive electricity generation at the time of mixing with seawater. The process can be understood as similar to the action of the regular electric cell, like the torch cell, where electrodes of carbon and zinc, with a different affinity to charges, are in contact with a chemically active medium.

In the case of seawater and fresh water, the electrodes contact water of different salinity, which also drives electricity, due to different electric properties, arising from a change of concentration, rather than of a chemical composition.

While getting energy out of fresh and saline water is now practical and has been applied, doing the same thing with gases has been elusive. What the Netherlands team has done is to develop a device that takes power plant exhaust, which is rich in $CO_2$ gas and mix the exhaust with ordinary air, which has low $CO_2$ content. The emission, with air separate, represents a state of low entropy (high order), which is destroyed when the gases mix. The arrangement developed is a method to harvest the energy released.

The cell consists of a pair of carbon electrodes in a container of water electrolyte. When the water is $CO_2$-rich, the gas forms carbonic acid, which splits into positive and negative parts and they move to the electrodes as allowed by the membranes provided. The electrodes get oppositely charged and there can be an electric current. The current soon stops as the charge build-up at the electrodes is compensated by charged particles taken up by the electrodes from the electrolyte. Now, if the water is replaced with air-flushed water, the ion build-up is reversed, till $CO_2$-rich water is pumped in, which builds up the charges afresh.

The flow of electricity that takes place during each cycle can be used and, in principle, the device becomes a generator of electricity. The Netherlands team experimented with different conditions and alternatives to water as electrolyte for better efficiency, but they note that much needs to be done before the process can be commercial.

The amount of electricity is a marginal, end of the process addition, but is not negligible. The potential energy from burning a tonne of coal is 6,150 KWH, and about 2,600 KWH in practice. In comparison, mixing a tonne of $CO_2$ with air can create some 73 KWH. Given the huge quantity of $CO_2$ generated the world over, there could be considerable energy created by this method "without adding to global $CO_2$ emissions", the authors of the paper say.

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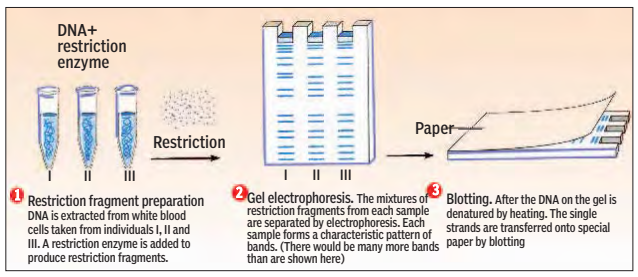
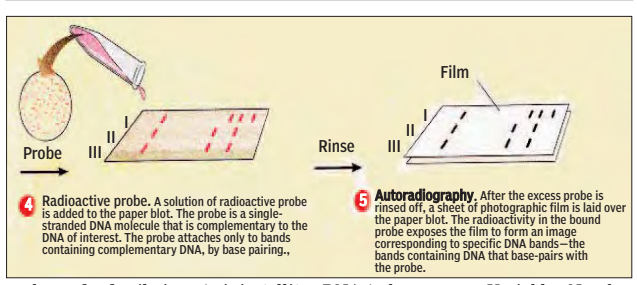
# DNA FINGERPRINTING

## **TAPAN KUMAR MAITRA** EXPLAINS THE AUTHENTICITY OF THE PROCESS

The analysis of restriction fragment patterns produced when DNA is digested with restriction enzymes has been exploited for a variety of purposes that range from research into the organisation of genomes to practical applications such as diagnosing genetic diseases and solving violent crimes. The practical applications of restriction fragment analysis are based on the fact that no two people (other than identical twins) have the same exact set of DNA base sequences. Although the differences in DNA sequence between any two people are quite small, they alter the lengths of some of the DNA fragments produced by restriction enzymes. These differences in fragment length, called Restriction Fragment Length Polymorphisms, can be analysed by gel electrophoresis. The resulting pattern of fragments serves as a "fingerprint" that identifies the individual from whom the DNA was obtained.




In practical usage, the technique of DNA fingerprinting is performed in such a way that only a small, selected subset of restriction fragment bands is examined. DNA fingerprinting might be used to determine whether individuals carry a particular disease-causing gene even though they may not yet exhibit symptoms of the disease. In the example given, imagine that individuals I, II and III are members of a family in which the disease-causing gene is common. It is known that individual I carries the defective gene but individual II does not, and we want to determine the genetic status of their child, individual III.

The key step in DNA fingerprinting is called Southern blotting (after EM Southern, who developed it in 1975), but the fingerprinting procedure actually involves several distinct steps. In (1), DNA obtained from the three individuals is digested with a restriction enzyme. In (2), the resulting fragments are then separated from each other by gel electrophoresis. Because each person's DNA represents an entire genome, hundreds of thousands of bands would appear at this stage if all were made visible. Here is where Southern's stroke of brilliance comes in, with a technique that enables us to single out the bands of interest.

In the Southern blotting process (3), a special kind of "blotter" paper (nitrocellulose or nylon) is pressed against the completed gel, allowing the pattern of DNA fragments to be transferred to the paper. In (4), a radioactive probe is added to the blot. The probe is simply a radioactive single-stranded DNA (or RNA) molecule whose base sequence is complementary to the DNA of interest — in this case, the DNA of the disease-causing gene. The probe binds to complementary DNA sequences by base pairing (the same process that occurs when denatured DNA renatures).

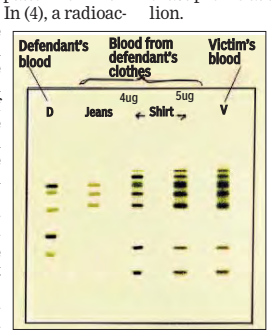
In (5), the bands that bind the radioactive probe are made visible by autoradiography. The results indicate that the child's version of the gene matches that of the healthy parent, individual II.

In another example of DNA fingerprints from a murder case, DNA was isolated from bloodstains on the defendant's clothes and compared, by RFLP analysis, with DNA from the defendant and DNA from the victim. The band pattern for the bloodstain DNA matches that for the victim, showing that the blood on the defendant's clothes came from the victim, strongly implicating the defendant in the murder. Another practical application of DNA fingerprinting in the legal area is the determination of paternity or maternity.

For many DNA fingerprinting applications, scientists now analyse the length of short repeated sequences (minisatellite DNAs) known as Variable Number Tandem Repeats. The VNTR sites chosen for DNA fingerprinting vary greatly in length from person to person because of differences in the number of times the basic repeat unit is sequentially repeated. As a result, the pattern of VNTRs in a person's DNA can be used to identify that individual uniquely.

For example, the DNA of three suspects in a murder case might all have different numbers of copies of the dinucleotide sequence TG at a particular place in the genome; one might have 19 copies, another 21 copies and the third 32 copies. The differences in restriction fragment patterns would come from the differences in the number of repeated (TG) units between two restriction cutting sites, rather than from the absence or presence of a cutting site as for traditional RFLPs.

In criminal cases, the lengths of 13 different VNTR sites in the genome are routinely examined. The chance that any two unrelated individuals would exhibit the same exact profile at all 13 sites is roughly one in a million billion.




The usefulness of DNA fingerprinting can be further enhanced by the Polymerase Chain Reaction, a technique for making multiple DNA copies. Starting with DNA isolated from a single cell, the PCR reaction can be used to selectively synthesise millions of copies of any given DNA sequence within a few hours, easily producing enough DNA for fingerprinting analysis of the 13 VNTR sites. In this way, a few skin cells left on a pen or car keys touched by a person may yield enough DNA to uniquely identify that individual.

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# Alien plant invasion

## SCIENTISTS AND EVEN THE MILITARY ARE BATTLING THE SPREAD OF HIMALAYAN BALSAM THROUGHOUT BRITAIN, WRITES **DAVID RANDALL**

An alien plant so bothersome that the Royal Marines have been called in to try to eradicate it, and so persistent that a top laboratory is working on a biological "secret weapon" to defeat it, has been helped to invade the British countryside by a fifth column of subversive flower lovers.

The Himalayan balsam grows up to 10 feet tall and has colonised large areas beside rivers and woods throughout Britain, smothering any indigenous plants. The Environment Agency, Plantlife, Wildlife Trusts and the National Trust all say the species is a headache and its total removal could cost as much as £300 million. But, with its pink orchid-like flowers, it is also attractive to many people.

It's so attractive, in fact, that a big factor in its invasive spread is people scattering its seed in the wild, according to research by Professor Ian Rotherham of Sheffield Hallam University and author of *Invasive and Introduced Plants and Animals*. He has plotted its spread around the UK, and the novel reasons for it.

Himalayan balsam (also known as Indian balsam) was introduced here in 1839 as a greenhouse and warm garden plant and, within a few decades, had escaped into the wild. It gradually established bridgeheads and then, especially after World War II, spread rapidly. Professor Rotherham's researches show that enthusiasts scattering its seeds far and wide were responsible.

His work, presented to environmental managers some years ago but not to a wider audience, quotes some examples of people who assisted the invader. There was a Miss Welch who, in 1948, collected seeds from Sheffield and took them to the Isle of Wight, where she sprinkled them beside a river near Newport; a Mrs Norris of Camberley in Surrey, who spread them to local waste areas and woods, gave them to passers-by, sent seeds to Ireland and even took them on holiday to France and Spain; plus people who, in recent decades, have carried the species from Norfolk to Newcastle, Aberdeenshire to Leicestershire, Hertfordshire to Essex and Bedfordshire, and Sheffield to the Peak District. Thus, the plant, also known because of the shape of its flowers as "policeman's helmet", spread. As Professor Rotherham puts it succinctly, "People like it!"

And once growing, Himalayan balsam can proliferate at a fearsome rate. Each plant produces an average of about 800 seeds, which means that a dense mass of the plants can contain a potential 30,000 seeds per square metre. And the explosive fruit pods can project the seeds several metres. So entertaining can it be to see the pods "pop" that it has even been marketed as a novelty for children — "Mr Noisy's Exploding Plant" — once sold by, among other outlets, Birmingham Botanical Gardens.

The upshot is that there is barely a part of lowland Britain free of this pretty menace. Fat stands of it clog small streams in places such as Somerset, and mass on the banks of rivers and woods from Cornwall to Scotland, with Norfolk, the Isle of Wight, New Forest, Hampshire, County Durham, Yorkshire, west Cumbria, Lancashire and North and South Wales especially troubled by it. The species is so prolific near Liverpool that it is known there as "Mersey weed".

Himalayan balsam grows in almost impenetrable thickets and will bully out any other species; its plentiful nectar means that bumble bees pollinate it rather than native species, and, being an annual, it dies down, leaving riverbanks bare in winter.

That is why, every summer weekend, conservationists organise clearing parties. This month, Royal Marines from the Commando Training Centre at Lympstone, Devon, joined volunteers to uproot the plants growing beside tributaries of the Otter river. Wildlife trusts as far apart as North Wales, Surrey and Cambridgeshire are calling up volunteers for anti-balsam efforts, and Professor Rotherham is working with groups on the urban Don river.

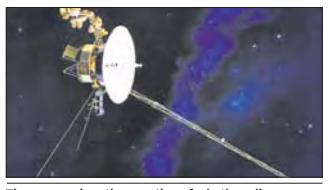
But as fast as it is cleared, it pops up elsewhere. A native of India and Pakistan, it has invaded 23 European countries, New Zealand, the USA and Canada. The ecological and financial cost of this is one reason why the laboratories at the Centre for Agricultural Bioscience International in Surrey have been working on a biological solution. Its scientists have discovered a rust fungus that seems to attack only Himalayan balsam and no other plant. If their safety tests find no problems, permission for the controlled release of the rust species will be requested from UK regulators. And, if all else fails, it could be eaten as all parts of the plant are edible, with the seed pods, according to Richard Mabey's authoritative *Flora Britannica*, having "a pleasant nutty taste".

THE INDEPENDENT

## PLUS POINTS

### Alien space probes

Researchers from Edinburgh University say that "self-replicating" robotic space probes from alien civilisations could already have arrived in our solar system. The probes, which mathematicians Duncan Forgan and Arwen



The paper raises the question of whether alien races could have used the gravity of stars to "slingshot" probes in order to gain speed: a technique humans already use for probes, such as the Voyager.

Nicholson referred to in their paper "Slingshot Dynamics for Self-Replicating Probes and the Effect on Exploration Timescales", could be so hi-tech that they're invisible to humans, they said.

The two mathematicians analysed the possibility that probes could travel through space in a study published in the *Journal of Astrobiology*. The paper raises the question of whether alien races could have used the gravity of stars to "slingshot" probes in order to gain speed: a technique humans already use for probes, such as the *Voyager* space probe, which uses a "slingshot" technique that features planets rather than stars, as the Scotland-based mathematicians suggest.

The researchers also analysed how a fleet of probes could "self-replicate" and build new versions of themselves from dust and gas while travelling through space. Dr Forgan said, "The fact we haven't seen probes of this type makes it difficult to believe that probe-building civilisations have existed in the Milky Way in the last few million years."

The scientists said, "We can conclude that a fleet of self-replicating probes can indeed explore the Galaxy in a sufficiently short time... orders of magnitude less than the age of the earth."

The new piece of research once again raises the so-called "Fermi Paradox" about the search for alien life. The paradox, suggested by physicists Enrico Fermi and Michael H Hart, is the apparent contradiction between the high probability extraterrestrial civilizations' existence and the lack of contact with such civilisations.

ROB WILLIAMS/THE INDEPENDENT

### Papaya-clay filter

Scientists are constantly pushing for water purification solutions that are inexpensive and robust and one such innovation is a hybrid clay synthesised by German and Nigerian researchers. The clay is actually a composite made up of kaolinite clay and papaya seeds. Writing in their paper, published in *ACS Sustainable Chemistry and Engineering*, they claim that the hybrid is stable, non-biodegradable, can be easily recovered from aqueous solution by decantation and available in large amounts. It also has a high cation (positively charged metal ions)

exchange rate, which means it can absorb and remove cations of metals like lead, cadmium and nickel from water.

Emmanuel Iyayi Unuabonah, one of the authors from the Department of Chemical Sciences of Redeemer's University, Nigeria, says, "We have not tried it on arsenic. But I am confident it will be able to remove arsenic from water since it is positively charged like the metal ions used in my research." Arsenic is one the biggest metallic polluters of groundwater in India. The hybrid clay is also yet to be tested for its ability to remove contaminating micro-organisms from water.

Commenting on their work, T Pradeep, professor of chemistry at IIT, Chennai, says, "Any technology is welcome in the water sector because the problem is huge." He has been working on developing solutions for water purification for a long time now and recently developed a silver-based nanocomposite material that can filter bacterial and viral impurities from water. This composite by itself cannot remove metallic impurities from water, but Pradeep and his team of scientists have teamed it up with other composites that have abilities to filter metallic impurities.

The resultant water purifier, which runs without electricity, can provide clean water to a family of five at an annual expense of Rs 150 assuming a daily consumption of 10 litres. The team published the findings in *PNAS* on 21 May 2013.

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