Electricity from waste gas

This summer, researchers at Wageningen University and Wetsus revealed how they can generate energy from CO_2. Since then, companies from around the world have been queuing up to collaborate with them.

TEXT RENÉ DIDDE **ILLUSTRATIONS** SCHWANDT INFOGRAPHICS

Generating electricity from waste gases: it sounds too good to be true. But it *is* possible, by making use of the huge difference in CO_2 concentration between flue gases from chimneys and the outside air. Making the carbon dioxide flow past electrodes with an aqueous layer causes protons and negatively charged ions to be produced. They pass through two selective membranes, after which an electrical current starts to flow.

The inventors of this process, researchers from the Environmental Technology section of Wageningen University, part of Wageningen UR, and from the water technology institute Wetsus in Leeuwarden, think it has huge potential. All the CO_2 from flue gases around the world represents a potential equivalent to 1.5 billion gigawatt-hours, around eight per cent of annual global electricity consumption.

BLUE ENERGY IN THE SKY

Using concentration differences to produce energy is not a new concept for the researchers.' You could see this new phenomenon as a spin-off from blue energy,' says Cees Buisman, professor of Biological Recovery and Reuse Technology in Wageningen and scientific director of the water technology institute Wetsus in Leeuwarden. In blue energy, electricity is generated by exploiting the difference in salt concentration between river water and seawater. A pilot plant for this is currently being built on the Afsluitdijk causeway. The new variant has a long way to go before it reaches that stage but this 'blue energy in the sky' has much greater potential. 'If we assume four to eight per cent CO_2 in flue gases and 0.04 per cent CO_2 in the air, we can profit from concentration differences of a factor of one to two hundred,' says Buisman. The salt concentrations of river water and seawater in blue energy differ by a factor of 60 at most.

Just taking the CO_2 from the chimneys of all the coal-fired and gas-fired electricity power stations around world (which pump thousands and thousands of cubic metres of waste gases containing CO_2 into the air every second) can generate electricity worth 50 billion euros per year. 'And the more old-fashioned the technology, the more carbon dioxide is produced and the better that is for our invention,' laughs Buisman. He says it is not a problem that these forms of fossil energy will eventually have to make way for renewable energy. 'Instead of coal, electricity power stations will increasingly be burning biomass and CO_2 is released then too. The same applies to the production of biogas and the fermentation of sludge or vegetables, fruit and garden compost.'

The proof of principle was demonstrated by the first author, Bert Hamelers, a researcher at Wetsus, and four other authors, including Buisman, in a paper in the journal *Environmental Science and Technology Letters*, which came out at the end of July.

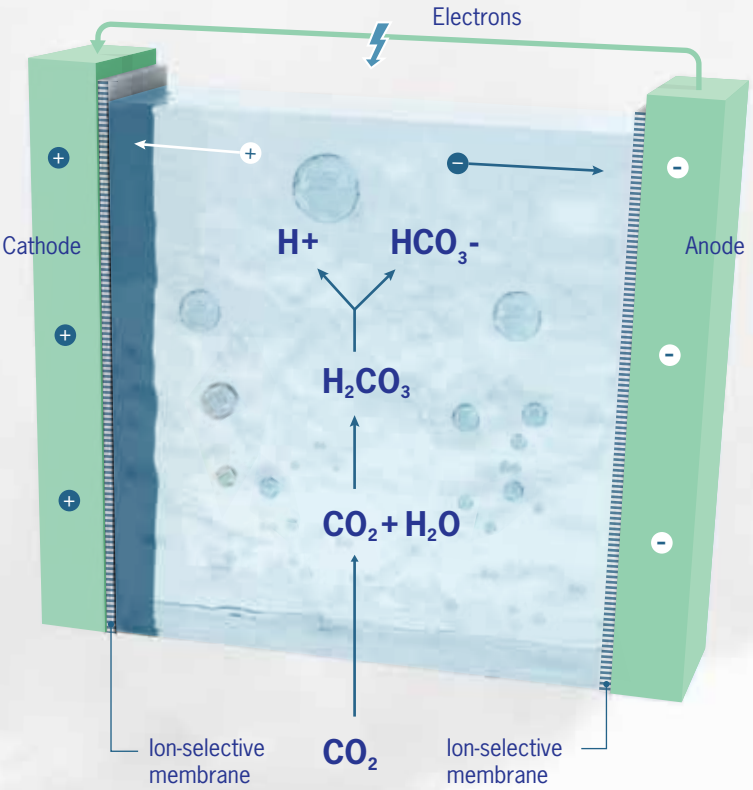
WATER AS INTERMEDIARY

Hamelers, who used to work at Wageningen University, used water as an intermediary for the energy generation. 'If the CO_2 in the flue gas is directed past electrodes with an aqueous layer, a simple reaction takes place that produces dihydrogen carbonate, H_2CO_3, which immediately splits into a proton (H+) and bicarbonate (HCO_3-),' explains Hamelers.

The protons pass selectively through a membrane towards carbon electrodes, where a surplus of positive charges results. The bicarbonate in turn goes through another selective membrane to other carbon electrodes, which leads to a surplus of negative charges. 'If you connect the electrodes, electrons move from the electrodes with a surplus of bicarbonate anions to the electrodes with a surplus of protons. So this generates an electrical current,' says Hamelers.

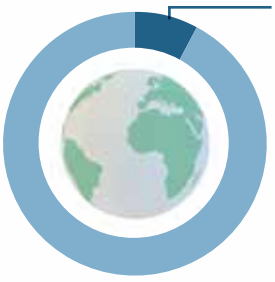
That process gradually slows down until the electrodes are completely saturated. 'Then you can close the valve with the flue gases and open the valve with the outside

ENERGY FROM CO_2



POTENTIAL

If all the CO_2 in the world that currently escapes into the air in flue gases were used, the theoretical potential would be 1,570 TWh per year.



8%

That is enough to provide 8% of the world's electricity consumption (as of 2008).

Source: Hamelers e.a., *Environmental Science & technology*

'The potential is enormous: 1.5 billion gigawatt hours'

air to start the process going in the opposite direction,' explains the researcher. 'The bicarbonate then wants to go back through the membrane to the channel with the low CO_2 concentration. An electrical current flows again and the CO_2 escapes into the outside air.' This means the invention is not a panacea for the climate problem.

FURTHER DEVELOPMENT

'It's a continuous process of charging and discharging, like in a battery,' says Hamelers. Since the publication, he has been approached by companies from all over the world eager to collaborate in the further development of the technology. He does not want to say too much: 'Some are companies that have a lot of spare CO_2 going while others are companies that need a lot of electricity. And of course lots of technology companies are interested, such as membrane manufacturers.'

In the short term, Wetsus wants to form a cluster of companies that can develop the technology to a marketable stage, as is being done with blue energy. 'You start in the lab, increasing reaction speeds and producing electricity in a test setup. Then eventually you try out a demonstration project in the chimney of a coal-fired power plant.' ■

Info: www.wageningenur.nl/co2emissions