GENERATING ENERGY WHERE SALT AND FRESH WATER MEET

Electricity from the Afsluitdijk

The planned renovation of the Afsluitdijk, the causeway between Noord-Holland province and Friesland, is the ideal opportunity for building a test plant for blue energy – electricity generated on the border between salt and fresh water. A large power plant could be appearing along the dyke within six years.

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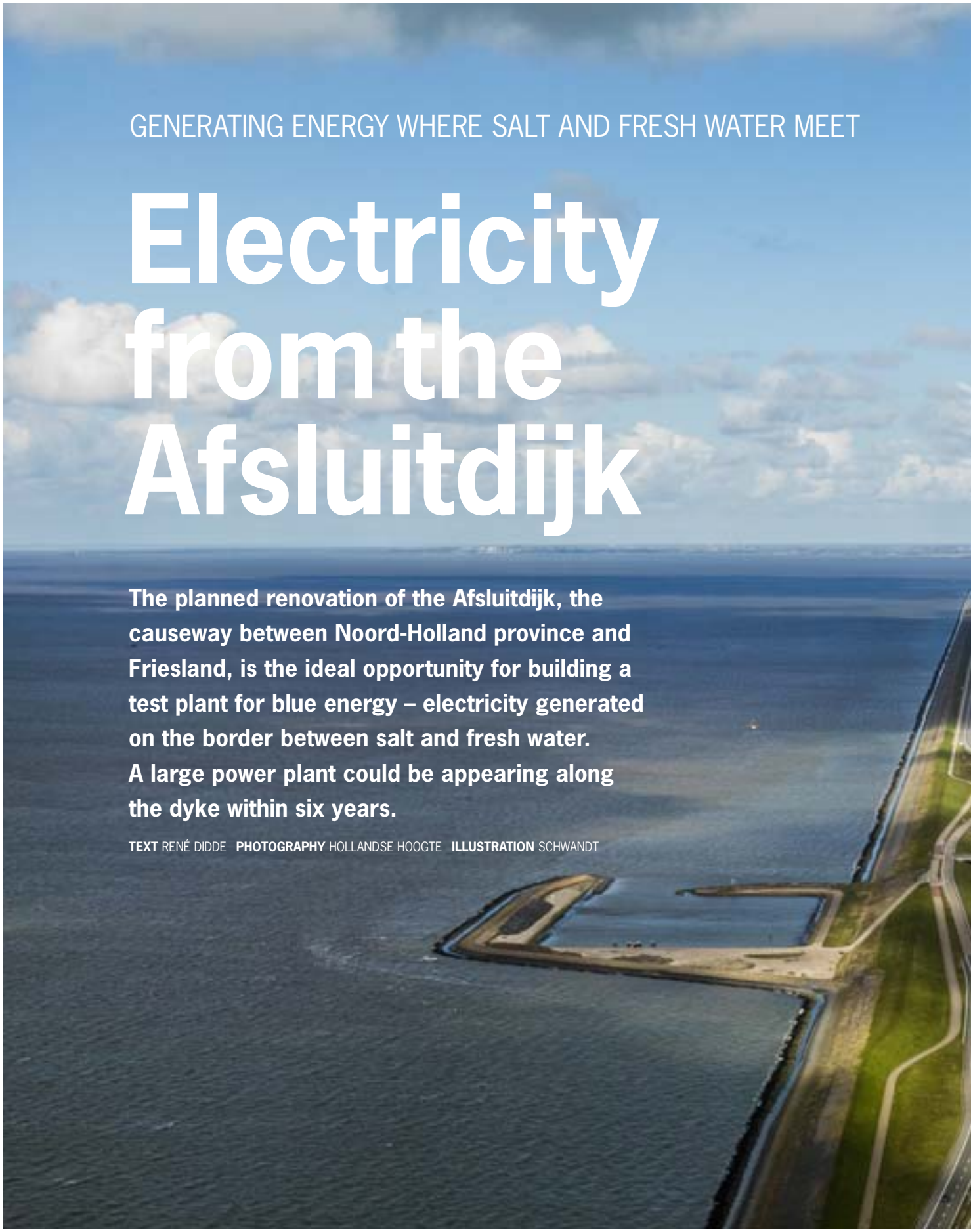


The first blue energy plant came into operation in Wageningen in 2006. It was on the lab scale – think 'shoebox' – and produced about enough electricity to run a modest fan. In 2009, the power it generated (0.1 watts) was increased fourteen thousand-fold to 1 kilowatt (1 kW) in the Frisia Zout salt factory. Sounds impressive – which it was, but this was still no more than the level of energy required to power a vacuum cleaner. Nevertheless, the underlying principle offers the prospect of an attractive new source of electricity, one that is particularly well suited to people living in a delta. Blue energy is based on the difference in the salt content of salt and fresh water.

Electricity can be generated by separating narrow compartments containing salt and fresh water by two kinds of membranes, explain Bert Hamelers and Cees Buisman. They are water technology experts at the Environmental Technology subdepartment of Wageningen UR and the specialist institute Wetsus in Leeuwarden. They have been involved from the very beginning in the scientific development of this environmentally friendly form of energy. Every second, energy is flowing from the river into the sea with the water. 'That's electrical energy we currently do nothing with', says Buisman. 'If we could bring the fresh water and salt water into contact in the right way, that would give you one or two power plants straight off.'

The preparations for this full-scale implementation are due to start in 2013. The site is the Afsluitdijk, the eighty-year-old 'grand old lady' of the Dutch waterworks (built in 1932) and precursor to the Delta Works. A small blue energy demonstration plant will start operating on the former construction site island of Breezanddijk. The plant will have several modules supplying a total of 50 kW, the equivalent of a Volkswagen Golf. If this plant is working properly after four years of research and the costs are not too high, a basic 200 kW module will be built.

ONE KILOMETRE LONG

'Then we can stack that module', says Pieter Hack. 'If we have about one thousand 200 kW units, we can build a power plant supplying 200 thousand kW, i.e. 200 megawatts (200 MW). So in six years' time we could erect a large power plant a kilometre long and four sea containers high', says Hack. An environmental protection engineer and Wageningen graduate, Hack is taking part in the blue energy experiments on behalf of Magneto Special Anodes. In his view, '200 megawatts is enough to satisfy the electricity requirements of all 500 thousand households in the northern Netherlands.'

SPIN-OFF

Wetsus has set up a spin-off company for the further development of the plant. It is called Redstack – 'Red' stands for *reverse electrodialysis* (reverse osmosis) and a 'stack' is a module of closely packed membranes. Redstack is a joint venture involving Magneto Special Anodes (where Pieter Hack works), the power grid company Alliander and A. Hak (manufacturer of pipes, cabling and high-voltage masts). Older partners are fibre manufacturer Landustrie and Hubert Stavoren (maker of microsieves among other things).

The construction of the 50 kW test plant on the Afsluitdijk and the research due to be carried out there will cost an estimated seven million euros. Half will come from the collaborative association of northern provinces (SNN) while Redstack will provide the other half. The consortium is collaborating with Wetsus in Leeuwarden and Fuji in Tilburg. Fuji is known mainly as the company that produced rolls of film but it saw the digital revolution in photography coming in plenty of time and switched to the development of wafer-thin membranes.

Their quality will be a decisive factor in the venture's success. The easier it is for the sodium and chloride ions to pass through, the greater a stack's efficiency. The so-called spacers – plastic netting used to maintain the distance between the membranes – also play a key role, according to Pieter Hack. 'They let the water flow more easily along the membranes and prevent contamination of the membranes.'

This is known as 'fouling' and is a cause of concern. Hack: 'If the membranes clog up like a coffee filter, the production of electricity will fall. We filter all microplankton and mud particles down to fifty micrometres out of the water but the really fine stuff still gets through.' Hamelers thinks it will be possible to flush the membranes clean by reversing the stacks so that the salt and fresh water flow in the opposite direction for a short while. 'Air bubbles may be able to help, or otherwise we could apply a small dose of chlorine to the stack every now and again.' The question is how that will fit in with the other plans for the dyke.

AFSLUITDIJK TO GET AN OVERHAUL

Outgoing state secretary for the Environment Joop Atsma (of the Christian Democrat party) says the dyke needs to be blue energy-proof. The Afsluitdijk will be getting an overhaul in about 2015 and the state secretary thinks space should be reserved for blue energy.

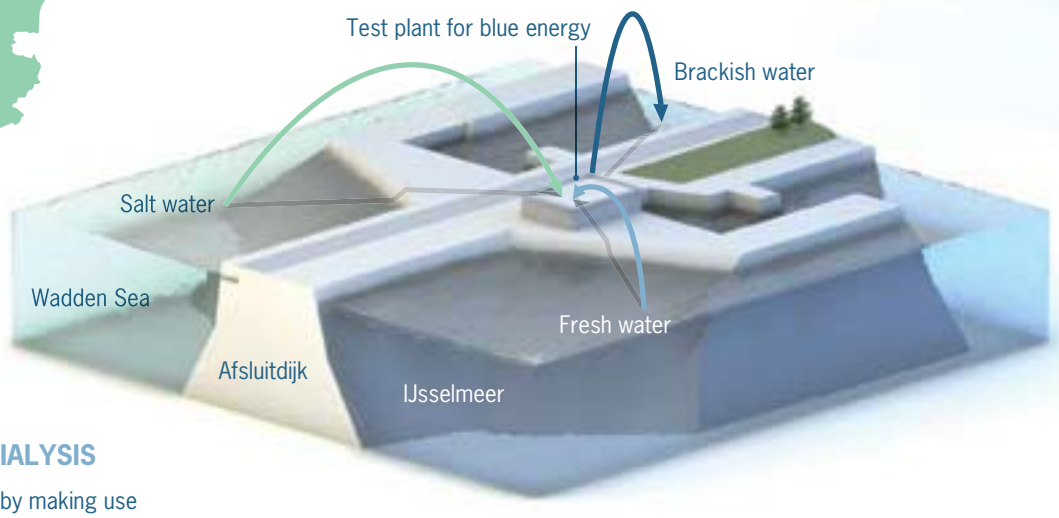
There is no doubt that the causeway is in need of major maintenance. 'After eighty years, the concrete in the two floodgate complexes at Den Oever and Kornwerderzand is showing signs of wear and tear', explains Yolande van der Meulen of the Directorate-General for Public Works and Water >

> 'If the membranes clog up, electricity production falls'

BLUE ENERGY

An electricity plant will be built on the Afsluitdijk to generate electricity from salt and fresh water.

The plant is supplied by fresh water from the Ijsselmeer lake and salt water from the Wadden Sea. Brackish water is discharged.



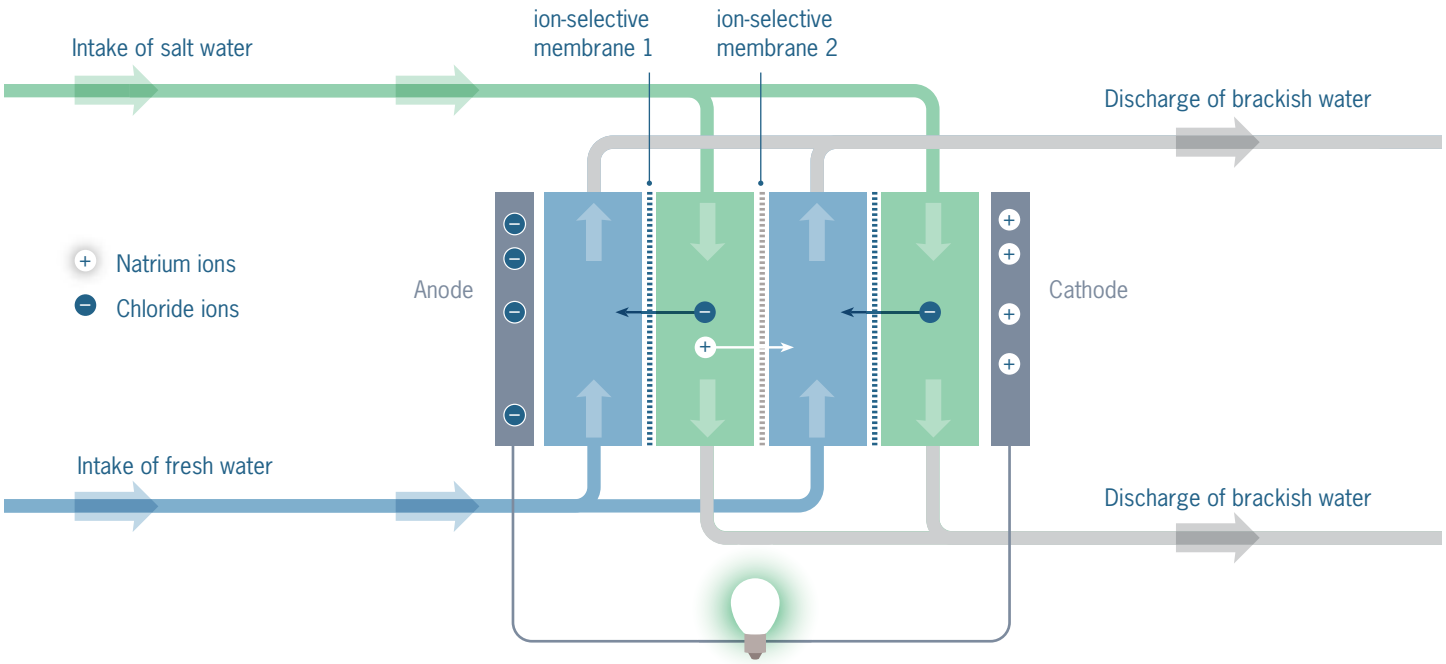
REVERSE ELECRODIALYSIS

Blue energy is generated by making use of reverse electrodialysis.

Salt water (containing sodium chloride) and fresh water flow through small, alternating segregated compartments past two different, ion-selective membranes.

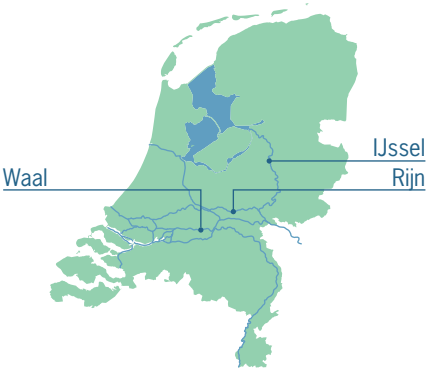
One membrane only lets through positively charged particles (natrium ions), the other only negatively charged particles (chloride ions).

The ions collect in the outer two compartments. One compartment now has a shortage of positive ions while the other has a shortage of negative ones. Wiring the two up together sets an electric current in motion.



MASSIVE POTENTIAL

Blue energy makes use of the difference in ion concentrations between fresh and salt water, and this makes it an interesting new source of electricity for the Netherlands.



Electrical power of river water that flows into the sea:

1 m^3 = 1
river water megawatt

Water flowing from the Rhine, Waal and Ijssel rivers per second:

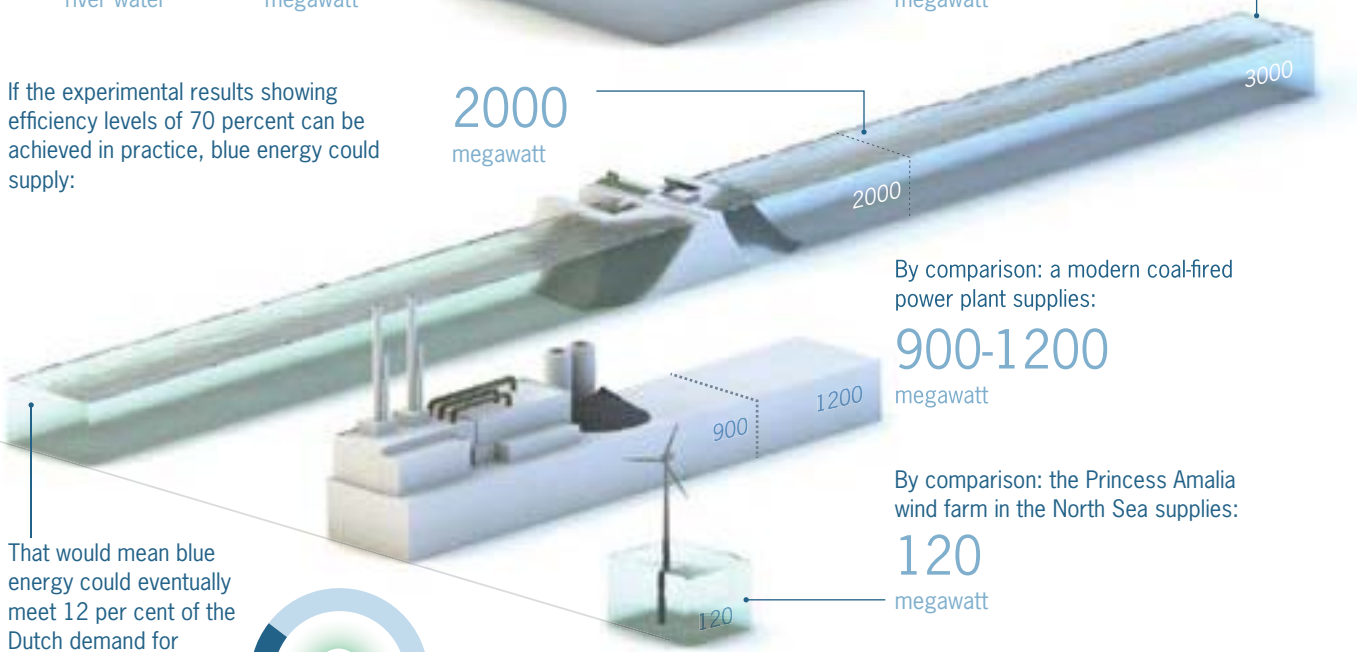
2700 m^3

Energy potential of blue energy for these Dutch rivers:

3000
megawatt

If the experimental results showing efficiency levels of 70 percent can be achieved in practice, blue energy could supply:

2000
megawatt



By comparison: a modern coal-fired power plant supplies:

900-1200
megawatt

By comparison: the Princess Amalia wind farm in the North Sea supplies:

120
megawatt

That would mean blue energy could eventually meet 12 per cent of the Dutch demand for electricity.

Future energy potential of afsluitdijk power plant:

200
kilowatt

Blue energy is also suited to smaller plants. Industrial companies or large organizations such as port firms could use blue energy to meet their own energy requirements.

If results are good a module for about 200 kilowatts will be built. One thousand units supply 200 megawatt (MW): enough to provide electricity for all the households in the northern Netherlands.

Management, who is responsible for the safety of the Afsluitdijk. With rising sea levels, both the flood gates and the dyke wil need reinforcing. 'The sluice capacity also needs to be increased given the expected rise in water levels in the IJssel Lake', explains Van der Meulen.

Blue energy is one of the ambitious schemes explicitly trying to take advantage of the dyke reinforcement project. Initially, four consortia came up with spectacular plans that focused on nature, recreation, transport and housing in addition to safety. For example, mudflats on the Waddenzee side could be used to break the worst of the waves while at the same time serving exceptionally ambitious objectives for nature. All four plans also incorporated a blue energy power plant, but because of the cutbacks none of the plans got further than a few sketches and artists' impressions.

Van der Meulen says 600 million euros have been reserved for safety improvements. 'Half of that will go on making the IJssel Lake side of the dyke resistant to water washing over and we will be spending the other half on reinforcing the civil engineering structures such as the sluices.' There are also 20 million euros available for 'regional ambitions'. The region itself will be contributing another 20 million.

ENERGY-NEUTRAL DYKE

Van der Meulen sees potential here for implementing the best bits of the earlier plans. 'That certainly includes blue energy, but first the researchers will have to show that everything functions properly in practice. One area for further research is the proportion of very fine particles of sediment being carried into the plant by the fresh IJssel Lake water', she says. Like another project involving solar panels, blue energy fits in with the goal of an 'energy-neutral dyke', according to the project manager. A scaled-up version of the test plant could supply the electricity for the lighting along the causeway and for the sluices and buildings.

The blue energy power plant also fits in with another interesting idea: combining the renovation of the Afsluitdijk with the construction of a so-called fish migration river. After the membranes have exploited the difference between salt water and fresh water in salt concentration, a substantial volume of mixed water, i.e. brackish water, will have to be discharged, and this could play a role in the transition between the salty Waddenzee water and fresh IJssel Lake water.

> 'Fish have to be able to smell the river from the sea'

At present, there is a brief window twice a day, just before the sluice gates open and just before they close, when fish can migrate from the Waddenzee to the IJssel Lake. They then have to undergo a salt-water or fresh-water 'shock' in one go. A permanent opening would make things easier – for example, in the form of an estuary lane straight through the dyke with a gradual transition from salt to fresh water. The idea is that this would connect up to a deep channel in the Waddenzee, the Doove Balg. It also needs to be constructed in such a way that no salt water enters the IJssel Lake.

The suggestion by Wetsus scientists Hamelers and Buisman is that the brackish water produced by the blue energy power plant could be used to attract the fish and serve as a transitional phase for fish swimming from salt to fresh water. The Waddenzee seems the most logical site for this but a location in the fish migration river could be another option.

'SMELLING' THE RIVER

That sounds appealing but some important questions still need to be answered, say scientists at the marine research institute IMARES Wageningen UR on the island of Texel. IMARES is one of the initiators of the fish migration river. 'First we would need to know more about the brackish water being discharged', says researcher Martin Baptist, who is also a lecturer at Van Hall Larenstein, part of Wageningen UR. It is important not to filter all the life out of the water if it is to attract spawning fish. 'Fish like the salmon and the Atlantic sturgeon, which need the major rivers for mating, have to be able to 'smell' the river while still in the sea', says Baptist. 'I am in favour of blue energy, but the project requires considerable preliminary purification. Will there still be animal and vegetable plankton and nutrients in the brackish water? And when I hear they may be using chlorine to flush the membranes clean, I want more information first.'

Furthermore, the IMARES researcher points to the massive flow of 400 cubic metres of water being discharged every second by a 200 MW power plant. Such a huge volume of water may not fit with the 'building for nature' concept that the designers of the fish migration river have in mind.

Cees Buisman and Bert Hamelers at Wetsus acknowledge that questions still need to be answered in terms of the ecological effects. 'We may need to mix the brackish water first with untreated salt water and fresh water, so that there are more sediment particles and minerals being discharged into the Waddenzee', says Buisman. Pieter Hack at Redstack agrees that further research is required on both the positive and negative effects on nature. Smart synergy effects between blue energy and nature could prove advantageous for future export opportunities. 'In South Korea, they are looking at the options for building a whole series of Afsluitdijk-like causeways', says Hack. 'What could be better than building blue energy power plants, improving safety and benefiting nature all at the same time? There are huge opportunities there for Dutch universities, engineering consultancy firms and dredging companies.' ■