

Tidal power? No thanks

The north of Scotland has been described as the Saudi Arabia of marine power. In truth there isn't much energy to be had, says **Hans van Haren**

THE vastness of the ocean has always created the illusion of infinite resources, whether for food or waste disposal. Yet despite its huge size, the ocean is vulnerable to exploitation.

The ocean also seems like an attractive source of vast amounts of sustainable energy, including tidal power. Just last month, four tidal energy schemes were given the go ahead off the north coast of Scotland with the aim of generating 600 megawatts of electricity. Scotland's first minister, Alex Salmond, described the waters as the "Saudi Arabia of marine power".

Again this is an illusion. In practice, only relatively small amounts of energy are available from tides, and extracting it will have devastating effects on the ocean ecosystem.

Tides created by the moon and sun generate about 3.5 terawatts



of power in total. This may sound like a huge amount, but is in fact only about 20 per cent of global energy demand. The amount of this energy that can be used is even lower: to make tidal power viable, the speed of the current has to be at least 1.2 metres per second. This rules out vast majority of tidal energy because it is found in the open ocean where tidal currents are too weak, generally less than 0.1 metres per second.

Viable speeds are only found in the shallow seas around the perimeter of oceans. In fact, there are only about 20 suitable sites in the world, including the north of Scotland and the Severn estuary in the UK. In the Netherlands a test plant is proposed for the Wadden Sea, a UNESCO World Heritage site.

Unfortunately, these sites are all in extraordinarily rich and ecologically fragile straits and estuaries that are critically important spawning grounds for marine life. Strong tides are what make these waters so productive: their turbulence stirs up nutrients vital for life.

In total, less than 100 gigawatts of power could be generated by the suitable sites, and it is debatable whether even this can ever be extracted efficiently. Tidal

The true cost of search

Even search engines must abide by the laws of thermodynamics, says **Jim Clarage**

HOW much does a web search cost? It may appear free, but appearances can be deceptive.

The term search "engine" is more apt than we think. Search is powered by millions of computers packed into warehouses, all wired together to function as a single system. Like any system it obeys the laws of thermodynamics, and

therefore wastes energy.

The first law says it takes energy to do work, even if that work is nothing more than moving electrons across silicon wafers. The second law says that no engine is perfect, meaning some of the input gets lost as heat. This is the entropy, or disorder, arising from your search.

A successful results page brings clarity and order to your corner of the universe, but down in the server farms things get messy. Thermal motions of silicon atoms agitate air molecules behind the CPU racks, generating heat. More energy must be fed in to cool this engine with computer fans and air conditioning units for the warehouses.

Whatever you search for it boils down to the same cycle: move atoms, then cool atoms. Both these steps consume energy. How much? Let's run through some numbers, using the leading search engine as our guide.

IT research firm Gartner

estimates Google's data centers contain nearly a million servers, each drawing about 1 kilowatt of electricity. So every hour Google's engine burns through one million kilowatt-hours. Given that Google serves up approximately 10 million search results every hour, one search has the same energy cost as turning on a 100 watt light bulb for an hour.

This doesn't bode well. Even though the average American performs just 1.5 searches per day,

"Whatever you search for it boils down to the same thing: move atoms, then cool atoms"

currents vary greatly over time and maximum power-generating currents are only a minor part of a tidal cycle. Even small decreases in current speed have large impacts on electricity generation.

Recent evidence also questions the efficiency of electricity generation once tidal barrages and turbines are in place (*Renewable Energy*, vol 33, p 2485). Obstructing 25 per cent of the area through which the tide flows alters currents so substantially that the potential power is no longer extracted efficiently. Thus permanently exploitable tidal power is reduced to a few tens of gigawatts.

On top of that, turbines kill up to 80 per cent of fish passing through them, and changes in current affect nutrient supply, thereby altering the ecology of estuarine life.

Tides are indispensable for life in shallow seas. Without them, ocean life would come to a halt. Extraction of their energy may seem attractive, but in reality there is very little tidal energy to be had – and what there is comes at high ecological cost. We should save the tides. ■

Hans van Haren is an oceanographer at the Royal Netherlands Institute for Sea Research in Den Burg

it is hard to imagine that this will not rise dramatically.

The US Environmental Protection Agency estimates computer data centers are responsible for 1.5 per cent of US energy use. How much more when we, and our gadgets, are doing hundreds of searches per day? Or when the planet's six billion all want equal access? We've all heard the future of information architecture is cloud computing. It just might be a cloud of CO₂. ■

Jim Clamage is a physicist at the University of St. Thomas in Houston, Texas

One minute with... Francisco J. Ayala

The \$1 million 2010 Templeton prize has gone to the geneticist some call the "Renaissance man of evolutionary biology"

You won the Templeton prize for arguing that there is no contradiction between science and religion. Many people would disagree.

They are two windows through which we look at the world. Religion deals with our relationship with our creator, with each other, the meaning and purpose of life and moral values; science has to do with the make-up of matter, expansion of the galaxies, evolution of organisms. They deal with different ways of knowing. I feel that science is compatible with religious faith in a personal, omnipotent and benevolent God.

And yet conflict exists. Why?

Religion and science are not properly understood by some people, Christians particularly. Some want to interpret the Bible as if it were an elementary textbook. It is a book to teach us about religious truths. At the same time, some scientists claim they can use science to prove God does not exist. Science can do nothing of the kind.

You talk about mutual respect between science and religion. How can we foster this?

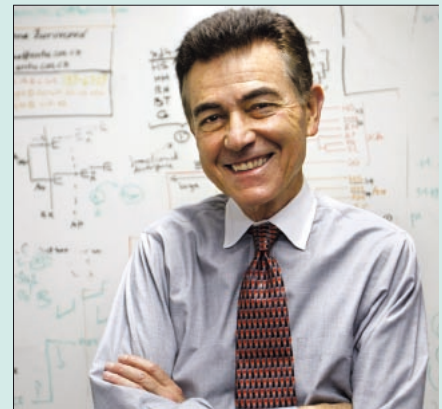
People of faith need better scientific education. As for scientists, I don't know what they can do: not many argue in a rational and sustained way that religion and science are incompatible.

Why do you say creationism is bad religion?

Creationism and intelligent design are not compatible with religion because they imply the designer is a bad designer, allowing cruelty and misery. Evolution explains these as a result of natural processes, in the same way we explain earthquakes, tsunamis or volcanic eruptions. We don't have to attribute them to an action of God.

One area where religion and science seem to be at odds is homosexuality. Who is right?

There is now evidence that predisposition to homosexuality is genetically determined, so there is a biological component and denying it is not right. Some religions condemn as immoral sexual relations between people of the same gender. That can be judged as a moral matter. One has to



PROFILE

Evolutionary biologist and geneticist Francisco J. Ayala of the University of California, Irvine, was a science adviser to President Bill Clinton, and was formerly a Dominican priest

distinguish what belongs to the realm of morality.

What is your response to atheists like Richard Dawkins who argue that we don't need religion to lead a moral life?

One can accept moral values without being religious. However, by and large, people get their moral values in association with their religion.

Do you believe in God?

I don't answer questions on my personal beliefs.

There are thousands of religions, many mutually contradictory. They can't all be right

Correct. It is a matter of faith. There is no way of demonstrating the superiority of one religion. True religion is what one person happens to believe.

I'm an atheist. Am I missing out?

No, because you can have a meaningful life without faith in God. But the majority of people live in poverty and misery, suffering from diseases. The one thing that brings them some hope and meaning is their faith, I don't want to take that