

# Frontiers



The BP magazine of technology and innovation

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## Capturing carbon dioxide

Locking greenhouse gases underground



**Into the fourth dimension**

Seismic surveillance through time

**Global insights**

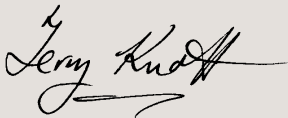
The world of location intelligence

## FROM THE EDITOR

Capturing carbon dioxide emissions and storing them safely in deep geological formations holds significant potential for combating greenhouse gas emissions associated with climate change. BP has established itself as a leader in understanding and developing the technologies required to achieve carbon capture and storage at scale – a range of operations that plays directly to the company's core strengths. In this issue of *Frontiers* we take an in-depth look at the technologies involved, and at BP's wider initiatives in helping to drive the carbon capture and storage agenda.

Other features in this issue focus on BP's advanced capabilities in activities as diverse as: seismic surveillance for monitoring hydrocarbon reservoirs over time; location intelligence – providing on-the-spot information to conduct operations more safely and efficiently; tailor-made greases to underpin the smooth running of industry; and subsea pumping in the deep waters of the Gulf of Mexico, where one of BP's pioneering projects has set new records in boosting production from oil and gas fields.

Wherever your particular interest lies in the broad world of energy supply, we hope you find this issue of *Frontiers* to be both engaging and informative.



Terry Knott, Managing Editor

## Frontiers

Issue 21, April 2008

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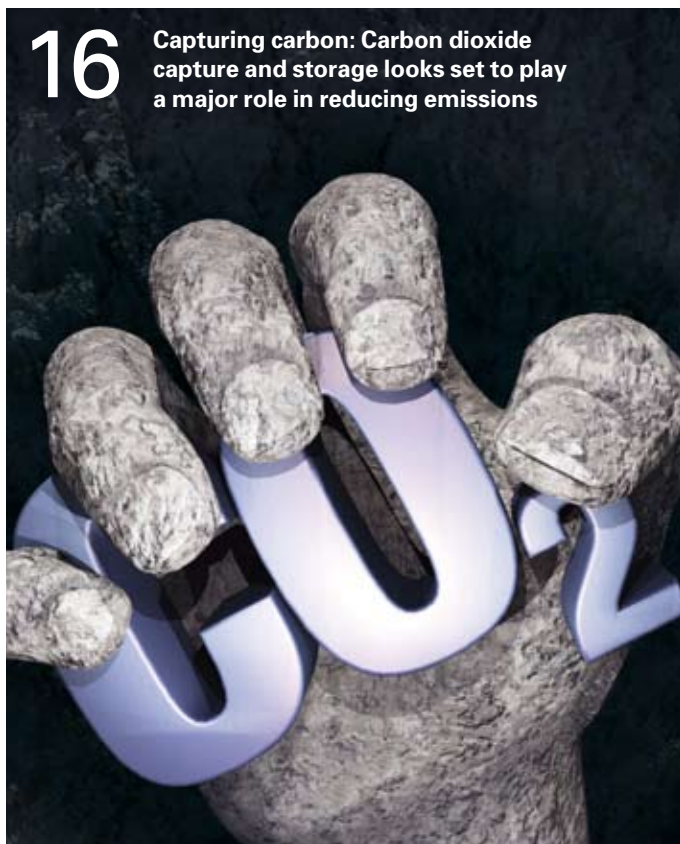
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**30** Sean Hennigan,  
separation specialist

## Clean power for Abu Dhabi

**Abu Dhabi has become the scene for a major initiative in low carbon, clean power generation. The country has unveiled plans for a multibillion dollar hydrogen-fuelled power generation project, to be coupled with carbon dioxide capture and storage, which could be in operation in 2012 and be the first industrial scale plant of its kind in the world.**

Masdar, Abu Dhabi's governmental initiative for renewable and alternative energy and clean technology, and Hydrogen Energy International, the joint venture between BP Alternative Energy and Rio Tinto, will be working together on the project's \$45 million front end engineering and design phase, which is expected to be completed by the end of this year.

At the heart of the plant would be a natural gas reformer and carbon capture facility where around three million cubic metres of natural gas per day, taken from the country's gas supply grid, would be transformed into hydrogen and carbon dioxide (CO<sub>2</sub>). The hydrogen gas would be used to fuel gas turbines and generate around 420 megawatts of electricity – equivalent to five per cent of Abu Dhabi's current power generating

capacity – with water vapour being the main emission. Some 90 per cent of the CO<sub>2</sub> generated would be captured and safely and permanently stored rather than being emitted to atmosphere, thereby limiting greenhouse gas emissions. Discharge of around 1.7 million tonnes of CO<sub>2</sub> per year would be avoided – the equivalent of 'decarbonising' Abu Dhabi's entire domestic transport sector.

The CO<sub>2</sub> would be available to replace natural gas that is currently being injected into oil fields to maintain pressure, freeing up the natural gas to fuel Abu Dhabi's continued economic growth within the United Arab Emirates, or to be exported. The CO<sub>2</sub> injected into the oil fields could potentially enhance the recovery of previously unrecoverable oil – possibly up to three billion extra barrels – and would remain stored securely and permanently in the impervious geological structures deep below ground (see feature on page 16).

Lewis Gillies, chief executive of Hydrogen Energy, said: 'Through Masdar, Abu Dhabi has shown strong leadership in creating the right environment in which hydrogen power with carbon capture and storage, and other



**Visualisation of the Masdar hydrogen-fuelled power generation project**

alternative energies, can be deployed successfully. The complementary skills of Masdar and Hydrogen Energy will be a formidable combination. We look forward to making this project a reality.'

The overall project would require total capital investment (excluding the investment in CO<sub>2</sub> transportation and storage) of about \$2 billion. Subject to the completion of the engineering design and agreement on an enabling commercial structure, the partners hope to make the decision to proceed with construction by

early 2009, enabling the plant to come into commercial operation three years later.

Hydrogen Energy is a 50/50 joint venture between BP Alternative Energy and Rio Tinto established in 2007 to focus on industrial scale, hydrogen-fuelled power generation using fossil fuels and carbon capture and storage. The venture has also proposed two other hydrogen-fuelled plants, one in California and one in Western Australia (*Frontiers*, August 2007). More information can be viewed at [www.hydrogenenergy.com](http://www.hydrogenenergy.com)

## Nanotechnology goes underground

**BP America is participating in the Advanced Energy Consortium (AEC), a privately funded, multimillion dollar research consortium dedicated to the development of microtechnology and nanotechnology applications to increase oil and gas production.**

Other members of the consortium, which is based in Houston, Texas, include Baker Hughes, ConocoPhillips, Halliburton Energy Services, Marathon Oil, Occidental Oil and Gas, and Schlumberger.

The Bureau of Economic Geology at the University of Texas at Austin's Jackson School of

Geosciences will manage the AEC on behalf of the funding members, while the Richard E Smalley Institute for Nanoscale Science and Technology at Rice University in Houston – which has extensive nanotechnology expertise – will be a collaborative technical partner.

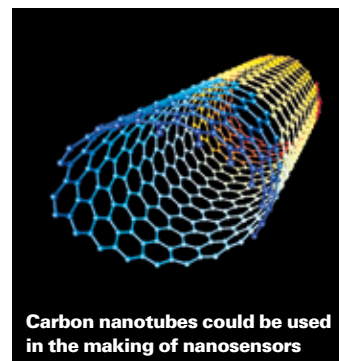
The AEC will solicit leading universities and researchers worldwide for competitive project proposals and the most promising will be funded by the consortium.

Geoscientists believe that more oil and gas can be extracted by improving understanding of the chemical and physical characteristics of existing oil and

gas reservoirs. Using current technology, typically 60 per cent of oil remains underground after primary, secondary and, in some cases, even tertiary recovery methods have been applied.

The consortium's primary goal is to develop tiny intelligent subsurface sensors that can be injected into oil and gas reservoirs to help characterise the space in three dimensions and improve the recovery of existing and new hydrocarbon resources. The size of these sensors could range down to a few hundreds of nanometres – one nanometre equals 10<sup>-9</sup> metres.

The AEC is beginning with a series



**Carbon nanotubes could be used in the making of nanosensors**

of forums in 2008 to bring leading nanotechnology experts together with oil and gas exploration and production technologists. The goal is to develop a technology roadmap which will serve to focus subsequent project proposals.

## China links

**BP has signed a series of agreements to enhance its commitments to China, involving strategic integration and commercialisation of clean coal conversion technologies, wind power generation and world-class acetic acid production.**

BP and the China Academy of Sciences (CAS) have agreed to undertake a feasibility study into a proposed Clean Energy Commercialisation Centre (CECC) joint venture, following the signing of a memorandum of understanding in Shanghai last August. CECC will integrate individual clean energy related technologies – including coal gasification, coal to liquids, coal to chemicals, carbon capture and storage, coal bed methane and underground gasification – from CAS institutes and other organisations both within and outside China, into competitive integrated feedstock manufacturing and product distribution systems.

In the wind power sector, BP has signed a framework agreement with Beijing Tianrun New Energy Investment Company with the intention of jointly investing, constructing and operating three 49.5 megawatt wind power plants near Bayan Obo in Inner Mongolia. The two parties have also agreed to explore further wind power investment opportunities in other areas of Inner Mongolia.

For the chemicals market, BP – the world's leading producer of acetic acid – and Sinopec plan to add a new 650,000 tonnes per annum acetic acid plant at their Yangtze River Acetyls Company (YARACO) joint venture in Chongqing. The world-scale acetic acid plant, using BP's proprietary Cativa technology, could be on stream in 2011, when the total production at the YARACO site will be over one million tonnes per annum, making it one of the largest acetic acid production locations in China.

## Butanol boost for biofuels



**The partnership between BP and biotechnology leader DuPont, set up to develop and commercialise next generation biofuels manufactured from renewable resources, is targeting advanced metabolic pathways for creating biobutanol. Testing of the advanced biofuel has demonstrated that biobutanol can increase the blending of biofuels in gasoline beyond the current 10 per cent limit for ethanol, without compromising performance (Frontiers, December 2007).**

Butyl alcohol, or butanol, is an organic alcohol that can be produced through the fermentation of sugars and starches present in

organic feedstocks, such as wheat.

The partnership has been developing biocatalysts to produce the butanol isomers 1-butanol, 2-butanol and iso-butanol – higher octane molecules that are of increased usefulness from a fuels perspective.

Fuel testing conducted over the last 12 months by BP demonstrates that high octane biobutanol at concentrations of 16 per cent delivers similar fuel performance compared to current 10 per cent ethanol blend gasoline fuels, indicating that butanol can help achieve higher penetration for biofuels into the gasoline market, and can be used in existing fuels infrastructure. Ethanol, currently the most widely produced biofuel,

easily absorbs water, causing it to separate out from the gasoline blend in storage tanks, fuel tanks or in distribution pipelines. It also has a higher vapour pressure than gasoline, hence it can evaporate from vehicle fuel tanks.

BP's results show that 16 per cent high octane butanol blends have the added advantages of vapour pressure behaviour and distillation curves comparable to regular gasoline and, unlike 10 per cent ethanol, do not phase separate in the presence of water.

Under the BP-DuPont partnership, there are currently more than 60 patent applications in the areas of biology, fermentation processing, chemistry and end uses for biobutanol. By 2010, the programme is designed to deliver a superior biobutanol manufacturing process with economics equivalent to ethanol.

BP and DuPont have previously announced plans to build a biobutanol manufacturing demonstration plant at BP's Saltend chemicals complex near Hull in the UK, capable of producing biobutanol from a wide variety of feedstocks.

## Second BP Fellow appointed

**BP has appointed its second Technology Fellow under the company's Technology Fellowships and Associates programme. Professor Vernon Gibson, a renowned chemist and Fellow of the Royal Society, has joined BP's research and technology group as part of the chief scientist's team. His responsibilities include providing strategic guidance, review and technical advice on all matters chemical across the business segments, with a particular focus on catalysis and conversion technologies.**

Gibson joins BP from Imperial College where he is Sir Edward Frankland Professor of Inorganic



**Professor Vernon Gibson**

Chemistry and heads catalysis and materials research. He received his doctorate degree from Oxford

University and was a postdoctoral fellow at the California Institute of Technology. He was elected to the Royal Society in 2004 for his contributions to catalytic science.

The BP Technology Fellowships and Associates programme was launched in 2006 – Technology Fellowships provide an opportunity for world-class academics to spend one to three years working in industry alongside BP's technology leaders in areas of strategic importance to the company. The first fellow to be appointed was Professor Ann Muggeridge (*Frontiers*, August 2007). There are also currently 15 Associates operating under the programme.

# Patents

## Carbon capture

The increasing challenge posed by climate change means that new technological solutions are needed to help reduce the emission of carbon dioxide (CO<sub>2</sub>) to the atmosphere when fossil fuels are burned (see feature on page 16). Jonathan Forsyth *et al* describe a process for converting natural gas to hydrogen and CO<sub>2</sub>, and then separating these two gases by using a thin metallic membrane. The hydrogen can then be burned to produce heat and power without CO<sub>2</sub> emissions, whilst the concentrated CO<sub>2</sub> gas stream can be safely stored underground where it cannot contribute to global warming. (WO2007-129024)

## Ethanol efficiency

Converting sources of carbon, for example natural gas, coal or biomass, into useful products is becoming increasingly important. Ethanol is one such product. In three patents, Leslie Bolton *et al* describe methods for significantly improving the efficiency of currently used processes for converting synthesis gas (a mixture of carbon monoxide and hydrogen) into ethanol. Two of the patents cover the recycling of by-products, thereby increasing process efficiency, while the third provides an effective means of capturing carbon dioxide produced as a by-product. (WO2007-138259, 138300 and 138303)

## Superior solar

In the continuing drive to improve both the efficiency of solar cells and their manufacturing processes, a patent application by Dave Carlson *et al* describes a solar cell where lasers are used to form all the electrical contacts to the cell in localised regions on the rear surface. This process has advantages over those used to make conventional solar cells since the back-contact of the cell can be fabricated at low temperatures and requires relatively few processing steps. In addition, the back-contact solar cell can exhibit superior performance to conventional cells since there is no electrical current collection grid on the front surface. (WO2007-126441)

## Smart tags

One of the major applications for radio frequency identification (RFID) technology is to keep track of equipment and inventory assets by tagging them (*Frontiers*, April 2006). In this type of application, the

individual items which are to be tracked are attached to, co-located with, or otherwise associated with RFID tags. In this invention Curt Smith *et al* have devised a means by which this technology can be adapted to personnel in industrial settings of all types, onshore and offshore, to help ascertain their individual locations should an emergency arise. (WO2007-145890)

## Greener muds

Drilling highly deviated wells and achieving the best possible hydrocarbon production requires the use of high performance drilling fluids (muds). Current field applications mainly use oil-based mud (OBM), in part because its very low filtration rate avoids the build-up of a thick filter-cake on porous rocks traversed by the well. The thick filter-cakes often associated with water-based mud (WBM) can cause the drill string to become stuck, incurring high costs in re-drilling. Furthermore a thick filter-cake and high filtration rates in producing formations can severely reduce well productivity. However, environmental concerns are promoting the replacement of OBMs by WBMs. Simon Duncum *et al* describe the

development of ultra-low filtration rate water-based drilling fluids that provide the benefits of low-risk drilling and maximum productivity normally associated with OBMs. The formulations contain 'green' polymeric surfactants that associate into stable micelles that seal the pores in the filter-cake and provide the required ultra-low filtration rate. (WO2008-001048 and 001049)

## Gas by wireline

Paul Lurie *et al* have invented a method of drilling a lateral well from a main wellbore to access small gas pockets that would otherwise not be produced into the main bore. The drilling system is deployed and operated on wireline from the surface. A downhole pump is used to transport the drill cuttings from the lateral well to the main well, where the main production carries them to the surface. The system is designed to operate at a lower cost than conventional drilling rigs, and reduces the risk of reservoir formation damage that can occur during drilling using conventional mud systems. (WO2007-122393)

## Mordenite magic

Glen Sunley *et al* have developed a new catalyst for improving the efficiency and

yield of the carbonylation of alcohols by carbon monoxide to produce carboxylic acid. The process utilises a mordenite catalyst that produces excellent yields of carboxylic acids. It has been found that improved activity and product selectivity can be achieved by using a mordenite which has been modified with silver. (WO2007-128955)

## Cost reducing catalysts

In three patent applications, Wayne Schammel *et al* have identified an exciting new family of oxidation catalysts – and processes for their application – which can operate in water, and do so without additional corrosive promoters such as halogens. The catalytic compositions and processes are useful for the conversion of substituted aromatic feeds to oxidised products such as carboxylic acids, under commercially attractive process conditions. The advantages of operating in water and without halogen sources as promoters include process simplification, lower metallurgy requirements and the elimination of organic acid solvents from the process, all of which result in lowering production costs. (WO2007-133973, 133976 & 133978)



**Bright idea:**  
A recent BP patent application proposes the use of lasers in the manufacture of solar cells, to simplify production and enhance cell performance

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