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German regulation threatens pipeline bottlenecks

By NJ Watson

Inadequate regulation is hampering investment in Germany's gas-distribution network and might mean Russian imports through the planned Nord Stream pipeline have nowhere to go when it arrives in Germany.

"The story doesn't end when you reach the EU border," Marcel Kramer, chief executive of the Netherlands' Gasunie told *WGC News*. "Our gas must be able to reach the markets that our customers want it to."

European suppliers, importers and infrastructure firms say more effective regulation must be put in place immediately to prevent serious bottlenecks in the system.

Bundesnetzagentur, Germany's network operator, said last month that from 1 October it would cut the fees 10 operators can charge – including E.On, Gazprom, Gasunie, Dong Energy and GDF Suez – by an average 25%. The new fees will be valid until 2013. As a result, gas companies say returns are too low to generate new investment.

"We're faced with inadequate systems in some countries," Kramer said. "Returns are simply too low."

Gasunie, an owner and operator of an important gas-transport system in northern Germany, has received over 25 requests from gas companies for new transport capacity. On 1 October, Dong Energy signed a contract with Russia's Gazprom to double deliveries of natural gas from 2012 through the Nord Stream pipeline, which will transport Siberian gas to northern Germany under the Baltic Sea.

While the German regulator and politicians of the federal states have acknowledged the gas companies' complaints and are prepared to discuss their concerns, the companies are concerned that their response lacks the necessary urgency.

"We're concerned about the speed and timing of any resolution, because the investment decisions for these projects are coming up now," said Kramer. "We can't wait until this gas is already coming."



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Marcel Kramer, chief executive, Gasunie, talks exclusively to *WGC News*



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Iran looks to lift gas output by two-thirds over next five years

By NJ Watson

Iran will raise its domestic gas production from 0.6bn cubic metres a day (cm/d) to 1bn cm/d by 2014, according to deputy oil minister and head of National Iranian Gas Company Azizollah Ramezani.

Ramezani said the government will use budgetary funds and tap international capital markets for project finance.

He appeared to play down the prospect of the Doha-based Gas Exporting Countries Forum (GECF) evolving into a gas Opec – and attempting to control gas prices by varying output.

The GECF's main objective would be to promote relations between suppliers, consumers and traders, and to accelerate the expansion of the global gas infrastructure. "This organisation will help consumers and suppliers," he said, adding that most contact so far has been between Iran, Russia, Qatar and Algeria.

The Netherland's Gasunie praised GECF for inviting consumer organisations, including his company, to participate in the producer-led dialogue. "We are fortunate in this world to have vast gas reserves, but to bring them to market we need to have co-operation and dialogue," said Mareel Kramer, chief executive of Gasunie.



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A very big thank you to "las dos Kirsties" for making it all happen (especially the champagne for the press)

Significant Colombian LNG exports on the horizon, says ANH's Zamora

By Tom Nicholls

Colombia could soon be a large gas exporter, says Armando Zamora, head of upstream regulator Agencia Nacional de Hidrocarburos (ANH).

As several big oil companies gear up to drill wells in gas-prone deep-water areas off Colombia's Caribbean coast, ANH believes there may be potential for launching more than one LNG export terminal.

"If exploration results in the Caribbean are what we are expecting, we may have more than one LNG project in the near future," Zamora told *WGC News*.

The exploration will start in earnest next

year, with five wells expected in 2010. Companies with acreage in the area include BP, Petrobras, state-controlled Ecopetrol, ExxonMobil, Hess, India's ONGC and BHP Billiton.

The Colombian energy sector has proved resilient to the recession, said Zamora, with investment expected to end 2009 roughly level with 2008's figure. And, so far in 2009, it has signed up around 60 exploration contracts – putting it on a par with 2008 with three months of the year remaining.

ANH also believes Colombia has "several trillion" cubic feet (cf) of reserves in shale-gas deposits north of the capi-

tal, Bogota, as well as large volumes of coal-bed methane. And it hopes to stimulate further gas exploration with a bidding round that it will launch in December – signing up companies by the second half of next year.

Colombian gas production amounts to 1bn cf/d, with 0.7bn cf/d consumed locally and the remainder exported to Venezuela.

The country's oil sector is also on a rapid growth path. Crude production has reached 0.67m barrels a day (b/d), up from 125,000 b/d in 2005. By the end of the year, the figure is expected to hit 0.7m b/d and ANH says the country is on track to reach 1m b/d by 2015.



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Azizollah Ramezani

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US gas in storage near record levels

By Derek Brower

Natural gas in underground storage in the US rose again last week, said the Department of Energy (DOE), reaching a record high of 3.66 trillion cubic feet (cf). That represented a jump of 69bn cf on the previous week – a “huge” rise, according to one analyst and well above market expectations.

And yet natural gas prices in New York are retaining much of the strength they have acquired since the summer’s rock-bottom trading. Nymex’s front month contract yesterday morning was trading at around \$4.90/m Btu.

Prices rallied following the DOE’s stocks announcement, to the bewilderment of some observers. “We must respect this rally, even though we do not understand the whys and wherefores of its origin,” said Stephen Schork, editor of the Schork Report market newsletter.

Bulls in the market have been helped by a cold front in Chicago and predictions for cooler weather across the US this winter. But the rig count – which at just over half last year’s level has provided another source of bullish sentiment – could be misleading, says Schork.

Last week, the number of US rigs rose by seven, to 1024 – 955 rigs fewer than in the same week of last year, according to services company Baker Hughes.

Rig count misleading

Yet the historically low count could be misleading, say analysts, because the productivity of wells in the unconventional-gas plays is rising. In other words, don’t trust the rig count – trust the volumes going into storage.

Meanwhile, the oil market also seems to be finding support from beyond the fundamentals. Yesterday morning, the front-month Nymex contract had firmed by \$0.32 a barrel to top \$72/b, despite a 310,000 barrels a day rise in supply in September, according to the International Energy Agency (IEA).

A weaker dollar, following news of meetings between top oil producers to discuss ditching the currency, was one reason for the rise. And the IEA warned the bulls: “Even though the pace of demand contraction is clearly easing, auguring a return to year-on-year growth by Q4 09, the outlook for 2010 is still fraught with uncertainty, as the IMF warns.”

Knowledge tested and perfected

Equipment manufactured by Air Products, a leading global industrial gas supplier, has contributed to the success of more Liquefied Natural Gas (LNG) operations internationally than any other company.



First introduced in 1972, the company’s C3 MCR process and associated equipment has been selected for more than 80% of the total worldwide base load liquefied natural gas production capability in Abu Dhabi, Algeria, Australia, Egypt, Indonesia, Malaysia, Nigeria, and Qatar among other countries. Earlier this year Air Products’ new AP-X liquification process technology came on-stream at the Qatargas 2 Train 4 LNG project in Ras Laffan Industrial City, Qatar. AP-X increases by 50% the single train LNG production capacity over the current generation of process trains.

In the UK, Air Products was chosen to supply nitrogen for two import terminals at the Isle of Grain and Milford Haven over the past four years, and following the award of these contracts, Air Products is now responsible for nitrogen blending nearly 10 per cent of the UK’s natural gas consumption – 113 billion cubic meters a year, for both domestic and industrial use.

The UK’s high-performing Oil and Gas industry, comprising some 4000 companies, relies upon the country’s strong and dependable knowledge base, built upon a foundation of academic, engineering and professional excellence, as well as a reputation for innovative research and development performance.

The UK’s capability in this important area has been established, tested and perfected over several decades of producing the North Sea’s oil and gas resources, and as such the UK is recognised as a global centre for the provision of high quality accredited skills development, training and competency testing.

UK universities and training institutions are established in all of the world’s leading oil centres, helping international clients to develop more efficient and safer workforces and increase productivity in operations.

This extensive knowledge base, together with a deep history of research and development, is demonstrated by Air Products, who offer almost 40 years experience in the design of liquefaction



processes and the commissioning and start-up of LNG plants.

Founded in 1940, Air Products has built leading positions in key growth markets such as semiconductor materials, refinery hydrogen, home healthcare services, and advanced coatings and adhesives.

In particular, it is in LNG where Air Products’ wide-ranging expertise is really demonstrated.

The contract for the new 4.4 billion cubic meter capacity LNG import terminal – the first in the UK for 20 years – on the Isle of Grain in the Medway Estuary, UK was awarded in 2005. In 2007, Air Products was granted the contract to supply nitrogen for a new 6 billion cubic metre capacity LNG import terminal, under construction by Dragon LNG at Milford Haven, South Wales. As increasingly global trading of LNG allows the UK to import from more sources than ever, Air Products have installed systems at the two terminals which inject a variable level of nitrogen into the different imports to ensure that the LNG is compatible with current natural gas specifications.

The UK oil and gas industry will remain an important player in the world energy scene for decades to come. The knowledge and customer focus that Air Products has gained from its long and wide experience, along with the technology at its disposal, makes it an indispensable LNG contractor.

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The age of easy gas is over

By Andrew Gould

Just as it is said that the age of easy oil is over, the same can be said for gas. The reserves exist: BP puts conventional gas reserves at over 185 trillion cm – representing more than 60 years of consumption at today's rate. But these reserves are becoming harder to develop.

The last three years have witnessed huge progress in North American shale-gas development. Unconventional gas now represents more than 40% of US production and more than 10% of world output, yet much remains to be done in characterising the quantity of global unconventional resources that include tight gas and coal-bed methane (CBM) in addition to shale gas.

Impressive results

The development of shale-gas reserves in North America has been possible using technologies that maximise the contact between the shale formation and the wellbore: horizontal wells that are drilled and then fractured hydraulically in multiple stages to enhance well productivity. These technologies have led to impressive results from newly developed formations such as the Haynesville Shale in Louisiana, where initial production rates are an order of magnitude higher than the early wells in the Barnett Shale in Texas.

Some of the technologies that have helped to achieve such results include the use of novel materials and equipment to target specific reservoir zones. Others employ micro-seismic-based real-time monitoring of fracturing operations to ensure the treatments are placed as effectively as possible. Such monitoring also brings enhanced efficiency to horizontal well fracturing through pumping only what is needed to place the fracture accurately. Similar productivity results are

being obtained in Canada's Montney and Horn River basin shales.

Conventional resources have their own set of problems. For example, the International Energy Agency says 43% of conventional gas reserves contain significant amounts of hydrogen sulphide and/or CO₂. In the Middle East, home to 40% of the world's proved reserves, 60% contain hydrogen sulphide, or sour gas. In the former Soviet Union, the corresponding figure exceeds one-third.

The challenges involved in managing increasing amounts of sour gas include the development of safe drilling and production technologies and processes that ensure well and facility integrity, while minimising the project's environmental footprint. For example, the highly corrosive nature of hydrogen sulphide leads standard equipment to suffer dramatic failure when used in high concentrations of such gas and special preparation becomes a necessity.

In one Middle Eastern well logged and tested by Schlumberger, four reservoir zones were identified. Downhole samples were successfully obtained for surface

analysis based on primary gas composition analyses run at the bottom of the well using new formation-testing technologies. These analyses indicated hydrogen sulphide levels of 37% in the main upper zone and 15% in the lower zone – fractions that had previously defied exploitation. A detailed analysis along the reservoir formation also provided extremely useful tools to characterise the flow properties of the different layers to ensure subsequent smooth production. The well is producing over 100m cm/y.

Tougher environments

Another area requiring technological development relates to exploration and production in much tougher environments, such as deep water and below salt layers. Developments in such areas have been the least affected by recent reductions in upstream activity and are building on experience gained in the Atlantic triangle between the US Gulf coast, Brazil and west Africa.

One example is offshore Egypt. The potential reservoir lies under 1,500 metres of water, in a tight-gas sand, at a total depth of around 6,000 metres, where it is

shielded by salt that blurs the seismic image and forms a potential drilling hazard. The main challenge is to design a drilling programme that maintains sufficient downhole hydrostatic pressure to control the well, but not so much that it fractures the formation, resulting in potentially dangerous fluid loss. To maintain this balance requires fine-tuning a mechanical earth model in real time using measurements made while drilling, such as pore pressure and formation strength parameters. This sophisticated combination was impossible five years ago.

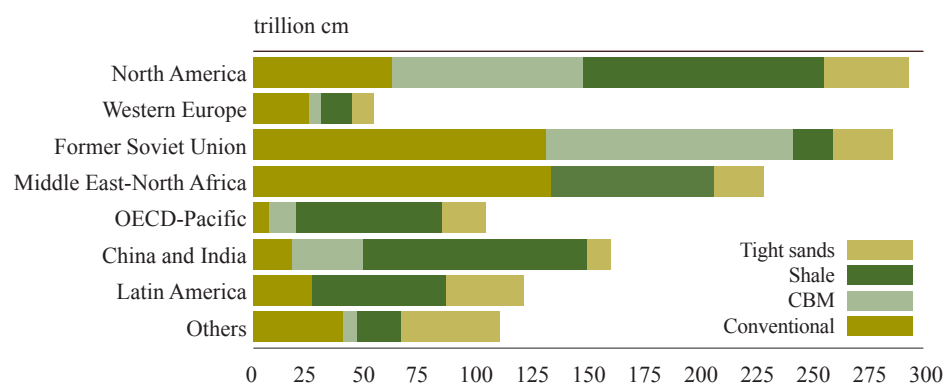
Deep, tight formations

A third technical challenge lies in deep and tight formations. Hydraulic fracturing techniques are well proved in shallow geological settings. More recently they have seen significant advances in deep and high-temperature zones. In a project in Oman, for example, numerous attempts had failed to break a tough target formation holding large volumes of gas. A complete geo-mechanical analysis of the reservoir rock, using the latest acoustic-scanner wireline-logging measurements, was undertaken. That led to a new formulation for the fracturing fluid, in which high concentrations of weighting particles provided enough weight to crack the formation.

Technology development in exploration and production is a long-term commitment and essential if the world's resources are to be utilised. But higher finding and development costs, coupled with lower product prices and more restrictive credit markets are stifling investment flows and this situation, if it persists, will lead to inadequate supply once economic growth returns.

Andrew Gould is chairman and chief executive officer of Schlumberger

Ultimately recoverable global gas reserves



Source: IEA, World Energy Outlook, 2008; BP Statistical Review of World Energy

US CBM producers send mixed signals

By Anne Feltus

The recession has taken a toll on the US coal-bed methane (CBM) sector. But producers have high hopes for the business and work continues to resolve environmental and operational issues that will position CBM for a strong comeback when market conditions improve.

Producers have reason for optimism. The Energy Information Administration (EIA) forecasts onshore CBM production will rise by 0.4% a year from 2007 to 2030, while conventional output will drop by 3.6% over the same period. The EIA estimates the country's CBM reserves at around 700 trillion cf, primarily in the western states, of which around 100 trillion cf is considered recoverable.

CBM has been produced on a limited scale in the northern Appalachian basin of West Virginia, Pennsylvania and Ohio since the 1930s and in the San Juan basin of the southwestern US since the early 1950s. Production rose in these and other CBM plays in the 1970s and early 1980s

after the DOE, the Bureau of Mines, the Gas Research Institute and energy producers teamed up to demonstrate that CBM could be produced commercially.

Then, in response to energy shortages in the late 1970s and early 1980s, the Alternative Fuel Production Credit was established to reduce dependence on foreign energy imports by encouraging unconventional oil and gas development. The measure triggered a CBM production boom.

Rising gas prices also served as an incentive. CBM output grew dramatically in the second half of the 1990s, exceeding 1.1 trillion cf/y by the end of the 20th century. Production totalled almost 2 trillion cf in 2008, says the EIA, accounting for about one-tenth of total US gas production.

However, in recent years, plummeting gas prices, rising costs and other factors have put the brakes on development. In 2007, drilling dropped by 24% and the number of permits issued fell by around 16%, according to industry sources. The country's largest CBM reserves are in the highly productive San Juan basin. In Colo-

rado, which encompasses the northern portion of the play, permit applications for CBM wells have dropped by about 60% over the last year – permit activity levels for 2009 are at about one-fifth of the total in 2000, the record year for applications.



In recent years, plummeting gas prices, rising costs and other factors have put the brakes on CBM development

According to the Coal Bed Natural Gas Association, at year-end 2006, about 19,000 CBM wells were producing in the Powder River basin of southeastern Montana and northeastern Wyoming, which holds the US' second-largest reserves. But by mid-March 2009, only a few CBM rigs were operating in the state according to the Wyoming Oil and Gas Conservation Commission. The agency is-

sued only 4,326 CBM drilling permits in 2008, down from 5,091 in 2007. The downturn is exacting a significant economic toll, especially on smaller CBM producers, several of which have filed for bankruptcy protection.

But some producers are forging ahead with expansion plans. BP plans to spend up to \$2.4bn over the next 12 years to raise CBM recovery in the Colorado portion of the San Juan basin by 1.9 trillion cf. Meanwhile, in second-quarter 2009, Range Resources drilled 61 CBM wells in Virginia's Nora field, one of the largest CBM accumulations in the Appalachian basin, and plans to drill 220 wells this year.

And the pace of CBM activity will pick up when the economy begins to recover. In anticipation, the industry, academia and government are collaborating on research projects aimed at developing techniques for increasing output, while reducing costs and mitigating environmental risks.

As gas prices rise and research projects reduce costs, CBM will become an increasingly attractive energy source.

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Iraq's gas infrastructure is barely developed, but just \$5bn is needed to develop Akkas and Mansuriyah

Tapping Iraq's gas potential

By James Gavin

Iraq's oil-production potential – up to 6m barrels a day – has understandably been the focus for IOCs. Yet the country hopes to become a significant gas producer and exporter, in a region where rising gas consumption is exceeding available supply.

The oil ministry knows it must begin developing its gas resources – estimated at over 3 trillion cubic metres by Cedigaz – but the four undeveloped gasfields included in the October and December licensing rounds failed to secure sufficient bids. The government plans to develop the Akkas and Mansuriyah fields on its own.

Most of Iraq's reserves are associated gas at its main oilfields – Kirkuk and Bai Hassan fields in the north, and the Rumaila and Zubair in the south. The only non-associated production, of around 2bn cm/y, is from the Anfal field, Kirkuk. The oil ministry estimated total output at only 14bn cm in 2006, with around two-thirds of that from the southern fields. Cedigaz put 2006 production at 12bn cm, with nearly 8bn cm flared or vented.

Oil minister Hussein al-Shahristani said in March that the country plans to raise output to 70bn cm/y, with exports beginning after 2012. The immediate aim is to

end flaring and free up more gas for domestic use – mainly for power generation and industry. In December 2008, the government signed a \$3bn contract with the US' GE, which it hopes will result in the country's electricity-generating capacity more than doubling. Although these power stations will initially be oil-fired, the plan is to convert them to gas.

The country's gas infrastructure is barely developed, but the investment outlays envisaged for the gas sector are much smaller than for oil. Shahristani says \$50bn of investment is required in the industry over the next five years; but of that, just \$5bn is needed to develop Akkas and Mansuriyah.

Huge need for investment

"Everything's still at the very early stages, but there's a huge need for investment, first and foremost to meet domestic requirements," says Alex Munton, Middle East analyst at Wood Mackenzie.

The country's largest gas project involves Shell's controversial agreement – signed with the government last year, outside the licensing rounds – under which the IOC would process and market all gas produced in the southern Basra region. If the deal is finalised – and it has become the focus of much political discontent, amid con-

cerns that the agreement would grant the major a monopoly over southern gas supply – Shell would build infrastructure to capture flared gas and use it commercially, to feed domestic power plants or for export.

More than any IOC, Shell has focused on Iraq's gas potential, seeing it as a lucrative supply source that would fit its Middle Eastern LNG portfolio – it holds stakes in Oman LNG (30%) and the under-construction Qatargas 4 (30%) project. In February, it brought in Mitsubishi as a partner in the venture, which also involves state-owned South Gas. LNG exports are likely at some point, although not until domestic demand is met.

But gas exports may still play some role in Iraq's more immediate energy plans. The location of the 60bn cm Akkas field, in the Western desert, near the border with Syria, far from Iraq's main population centres, makes exports to Syria a more suitable prospect than domestic usage. Akkas is also close to existing Syrian infrastructure, which would make field development significantly less expensive.

Iraq plans to build a gas pipeline to Syria, possibly to connect to the Arab Gas Pipeline that links Egypt and Syria. Iraq is also seen as a potential supplier to the Nabucco pipeline project, if it goes ahead.

Reaching stranded LNG markets

By Håkan Werner

Small-scale LNG is an effective solution for delivering gas to markets not connected to pipeline networks. Target markets are industrialised, but lightly populated countries and islands. Because the concept makes it possible to distribute LNG in small and medium-sized parcels, it will open up new markets, such as marine fuels and heavy-goods vehicles.

Small-scale LNG increases the market for gas by distributing LNG directly to end-users from a liquefaction plant, import terminal or from a ship using a combination of sea and land-based transport.

Small-scale concept

The concept shares much of its technology with the traditional LNG industry, but the approaches to marketing differ. Large-scale trade concerns the intercontinental transport of millions of tonnes LNG from export plant to import terminal and delivery into a national pipeline grid. Small-scale LNG is a more regional business: hundreds of thousands of tonnes of LNG are transported from a production facility direct to end-users, using various modes of transport – from ships to semi-trailers and ISO containers – making LNG, and natural gas, as easy to access as any other liquid fuel.

Using smaller ships – IM Skaugen's Multigas carriers have capacities of 10,000-12,000 cubic metres (cm), compared with up to 266,000 cm for LNG carriers – means the receiving terminals are also small. A terminal with 20,000-30,000 cm of storage capacity would be more than sufficient to allow

for full cargo unloading while maintaining stock levels. Compared with the capacity of existing import terminals – up to 2.6m cm – not only will a smaller terminal require much less capital, but it will be faster to build, and probably be easier to secure local construction and environmental permits.

The market for small-scale LNG could be described as stranded customers – too far from pipelines or too small to merit a pipeline extension. Pipelines normally reach most industrial areas, but there are exceptions, such as Scandinavia – where neither the topography nor the demography make pipeline investment a priority – or islands that will never be connected to a grid and where demand does not justify the cost of a traditional regasification terminal.

Small-scale LNG would enable power plants in these stranded markets to switch from oil-fired generation, to cheaper, cleaner gas. Environmental benefits would also be gained in the marine bunkers market. As legislation covering the shipping industry becomes tighter, emissions of sulphur dioxide (SO_x) and nitrogen oxides (NO_x) must be reduced and, eventually, this will apply to CO₂. Gas is the only fuel that can address these issues. As a marine fuel, gas can reduce SO_x emissions to zero, reduce NO_x by 80-90% and CO₂ by 20-25%.

Because small-scale LNG will never compete with gas head on, the relevant cost comparison is with liquid fuels, such as fuel oil, naphtha, diesel and LPG. Compared with premium liquid fuels, the potential economic benefits of small-scale LNG are significant. As well as lower emissions, increased gas use should result in improvements in generating efficiency.

The rewards for first movers are significant. The principal problems in developing the sector lie at the opposite ends of the supply chain. Transporting LNG is the easy part, but convincing customers to switch, not only to a new fuel, but also to a new supplier using a novel supply chain concept has required some work. And few customers will commit unless the supplier has committed itself and is building the supply chain, making financing difficult.

At the other end of the supply chain is another significant obstacle – the supply of LNG. Collecting LNG at an import terminal or a large export plant may appear technically straightforward, but this is not necessarily the case: infrastructure and equipment such as fenders, mooring arrangements, gangways and pumping capacity

differ from large-scale LNG and must be specially designed for smaller applications.

Norway is a first-mover country in the small-scale LNG business. The country's market amounts to about 120,000 tonnes a year (t/y). But when Nordic LNG's 300,000 t/y gas-liquefaction plant comes on stream in 2010 a large proportion of stranded Scandinavian and northwest European markets can be supplied. The potential market, including industrial users and marine bunkers, is in excess of 3m t/y. Nordic LNG – a partnership between Lyse and IM Skaugen – is the second operator to build an integrated LNG supply chain in Norway.

Håkan Werner is vice-president, business development, LNG, IM Skaugen, hakan.werner@norgas.org



Nordic LNG's 300,000 t/y gas-liquefaction plant comes on stream in 2010

Separating climate fact from factoid

By Derek Brower

If you leave your DVD player on stand-by all day instead of shutting it off then you're consuming the same amount of energy that it takes to ship the entire thing by plane from China, where it was made.

If you read that and didn't blink, then you've been infected by a global-warming disease, one that leaves you unable to tell fact from factoid, truth from hogwash.

If you flew across the Atlantic to Argentina, then by the time you get home again you'll have pumped into the atmosphere more than a third of the carbon each human emits, on average, every year.

That one's true. And those flights will have used the same energy you'd consume leaving a 1 kilowatt (kW) fire on, non-stop, for an entire year.



Bailing out the Titanic with a teaspoon

When everyone from scientists to politicians to journalists are batting forth statistics about climate change – gigatonnes here, 2°C temperature rises there – it's hard to keep the truth straight. And, says David MacKay, a physicist at the University of Cambridge, it can be dangerous to get it wrong.

McKay's book on how to arrest climate change, *Sustainable Energy – without the hot air*, came out in December 2008. It's a realist's guide to what renewable and other non-hydrocarbon sources of energy could do, and what they can't.

The work is a masterpiece of forensic analysis. Taking the typical Briton as his model, McKay calculates what his or her daily energy needs are – about 125 kWh a day (kWh/d), excluding imports of goods – and what proportion of them might feasibly come from green energy.

It's a fairly gloomy conclusion. The UK's theoretical supply from a range of sustainable energy sources could meet the bulk of demand. But politics and the country's talent for saying no to new developments means that the maximum UK citizens will ever get from renewables is likely to be around 18 kWh/d. That means green energy would contribute a paltry 15% or so of demand.

One target of the book is that "every little helps" in the fight against global temperature rises. When he set out to write his book, the UK had developed a fixation for switching off mobile-phone chargers.

"All the energy saved in switching off your charger for one day is used up in one second of car-driving," writes MacKay. "The energy saved in switching off the charger for one year is equal to the energy in a single hot bath." Such solutions are like "bailing out the Titanic with a teaspoon".

Meanwhile, freakish weather patterns seen in recent years – such as the blistering hot summer of 2003 that killed thou-

sands in Europe – will become more frequent while the world stalls on reversing climate change. But the real catastrophe, if nothing is done now, awaits "the people living on your street in 200 or 300 years".

So what's the solution? "We need an energy plan that adds up," says MacKay. Existing proposals are insufficient. To supply the UK alone with carbon-free energy, says MacKay, the country needs a 100-

fold increase in wind power, a five-fold increase in nuclear capacity and cables connecting "Surrey to the Sahara", where solar panels in the desert could be one of the most promising ideas of all.

Otherwise, get used to a hotter climate. MacKay says his next book could be about "geo-engineering" – how to adapt to a world of rising temperatures, melting ice caps and flooded lowlands.

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