# Plugging and Abandoning Hurricane-Damaged Wells

## Vented Inflatable System Eliminates Gas Bubbles, Enables Successful Cement Plugs

Many hurricane-damaged wells in the Gulf of Mexico have to be permanently plugged and abandoned. Operators have discovered that many of these wells are bubbling, which creates challenges when placing cement barriers in the wells.

### Gas Bubbles Passing Through Microannuli

Inflatable packers such as Baker Oil Tools' Production Injection Packer (PIP), deployed as a pressure sealing base on which a cement plug is placed, is often a suitable fix for this problem. However, gas bubbles sometimes find a way around the PIP and work their way through the cement, creating microannuli even after the cement sets up. These bubbles travel through microscopic pits or fissures in the old casing. This was the challenge an operator faced in a High Island well with 26-in., 125 lbf casing.

### Vented PIP System

To solve this problem reliably and economically, Baker Hughes developed the Vented PIP System, a new method of stopping the flow of bubbles. The system consists of a PIP (with a ball on seat below it), a length of vent tubing above it, and a mechanical disconnect on top of that.

### Bubbles in Well Stopped Immediately

Once the system was set at depth, bubbles in the well stopped immediately. Simultaneously, a substantial flow of gas was observed through the work string at surface. The operator then ran a grout string (small work string) beside the primary work string to a depth just above the inflated element. Cement was then pumped through the grout string on top of the PIP. A cement volume was pumped that equaled about 50 ft in the annulus between the 26-in. casing ID and the OD of the 2 7/8-in. tubing. While this cement cured, the vent tubing and work string were kept open to vent the gas to surface. This prevented gas buildup below the PIP and kept bubbles from affecting the cement job. Once the cement had completely cured, a cast iron bridge plug was run through the primary work string and set in the vent tubing above the PIP. This resulted in a permanently plugged well.

www.bakerhughes.com/bakeroiltools



BAKER HUGHES


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| Petrochemical | 18,882 | 8,264 | 50,755 | 38,598 | 35,863 | 19,268 | 5,911 |
| Liquid Terminals | 8,457 | 2,983 | 28,325 | 22,693 | 19,142 | 8,933 | 2,637 |
| Gas Utility | 13,768 | 6,645 | 47,288 | 37,118 | 31,035 | 15,903 | 4,873 |
| Electric Utility | 27,586 | 13,117 | 81,906 | 62,193 | 49,642 | 25,432 | 9,160 |
| Drilling & Well Servicing | 15,275 | 6,745 | 37,279 | 28,303 | 23,639 | 12,974 | 3,691 |
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| International E&P | 10,796 | 4,647 | 25,495 | 16,684 | 16,869 | 7,459 | 2,818 |
| United States & Canada E&P | 38,595 | 23,500 | 81,713 | 51,098 | 54,145 | 27,242 | 6,758 |
| Texas E&P | 11,760 | 7,820 | 31,857 | 22,614 | 19,578 | 9,921 | 3,101 |
| Houston & Gulf Coast E&P | 10,403 | 6,307 | 32,722 | 24,387 | 18,347 | 9,409 | 3,626 |
| Mid Continent & Eastern US E&P | 12,370 | 8,407 | 29,854 | 18,954 | 20,142 | 8,900 | 2,576 |
| Rocky MTN & Western US E&P | 9,539 | 6,256 | 21,603 | 13,119 | 13,860 | 6,710 | 1,647 |

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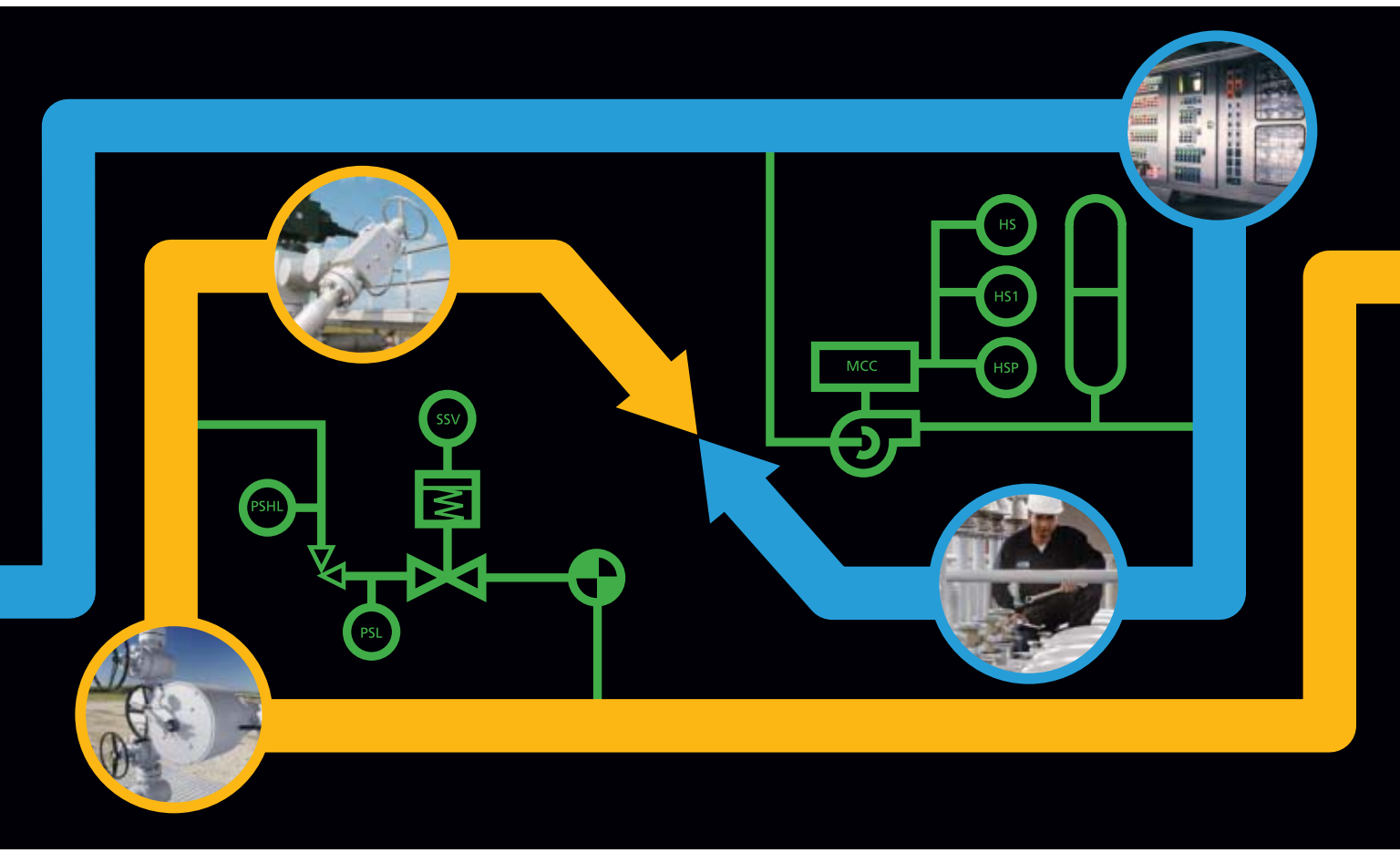


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## CANADA'S GAS OUTLOOK



## REGULAR FEATURES



## COVER

Production of natural gas from shale is expected to grow in Canada as conventional production declines (see special report, p. 18). One emerging play is the Triassic Montney shale of British Columbia and Alberta. Shown here is the Portage 8-23-81-26 well drilled by Triumph Pacific Oil & Gas in 2007 near Hudson's Hope, BC, and deepened into Montney shale in 2008 by Crew Energy Inc. and Canada Energy Partners Inc. In August, CEP reported the vertical hole encountered porosities exceeding 3% in 114 m of the Montney and Triassic Doig formations. After a slick-water frac, the Doig tested 946 Mcfd intermittently. The Upper Montney had characteristics similar to productive Montney wells nearby and wasn't tested. Crew suspended the well pending drilling of another test. Photo courtesy of Canadian Energy Partners.

# CONSTRUCTION PROJECT Data To Count On!

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The PennEnergy editors and the OGJ Online Research Center are regularly conducting intensive survey efforts tracking new energy construction projects worldwide, keying the details into a spreadsheet and making them ready for your use!

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- Petrochemical
- Refining
- Pipeline
- Gas Processing
- LNG
- Sulfur

The Excel format enables efficient and rapid analysis of planned construction projects. The data collected includes Company, Location, Capacity, Expected Completion Date and Current Status, Contractor, Cost, Engineering and Process Design (when available). Some of these surveys are also available in historical version going back to 1996.

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Contains upstream projects in 47 countries, shows the development of individual fields, and the supporting infrastructure. The Survey in Excel spreadsheet identifies:

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- project name
- operator & company name
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- cost when available

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## Offshore Drilling Rig Construction Survey

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## Oil Sands Projects

Planned Canadian Oil Sands development projects in four Excel worksheets. Includes: mining upgrading projects, in situ projects, reserves estimate of initial in-place bitumen, and historical table, commercial, experimental and exploration wells.

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## General Interest



## Exploration & Development



## Drilling & Production



## Processing



## Transportation



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Dec. 14, 2009

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## General Interest — Quick Takes

### NGSA, AXPC chime in on OTC market reform

US House floor action to reform over-the-counter derivatives markets could increase commercial hedging and risk-management costs enormously unless it includes language specifically excluding these activities, two oil and gas association executives warned.

Mandatory clearing of all OTC derivatives could remove as much as $900 billion from a fragile US economy, the presidents of the Natural Gas Supply Association and the American Exploration & Production Council said in a Dec. 4 letter to US House Speaker Nancy Pelosi (D-Calif.) and the Agriculture, Energy and Commerce, and Financial Services committees' chairmen and ranking minority members.

"Mandating centralized clearing and margins is a recipe for unintended negative economic consequences," NGSA Pres. R. Skip Horvath said in a separate statement. "If all estimated hedging transactions are forced into clearing, it could either cost the US economy an estimated $900 billion—the price tag of the entire 2009 economic stimulus package and then some—or force many companies to scale back their hedging, exposing customers to increased commodity and financial risk," Horvath said.

He added, "It would cost the energy industry alone tens of billions of dollars, effectively drive smaller participants out of the market and centralize risk, all at a time when dollars are instead needed to create energy jobs, build infrastructure, and meet environmental goals. That's the exact opposite of the effect that policymakers intend and couldn't come at a worse time for the struggling economy."

An OTC derivatives regulation provision is part of a financial reform bill sponsored by Financial Services Committee Chairman Barney Frank (D-Mass.) that the House was scheduled to consider on Dec. 9.

In their letter, Horvath and AXPC Pres. Bruce Thompson said there needed to be an exemption for energy derivatives used for hedging. Without a clear exclusion, physical natural gas supply agreements risk being defined as swaps and included in a clearing mandate, they indicated.

"Mandatory clearing is too high a price for energy derivatives transactions that do not contribute to systemic risk," Horvath maintained.

### DOE's CCS funding includes project in W. Texas

The US Department of Energy will provide $350 million to support a project designed to capture carbon from a proposed electric power plant near Midland-Odessa, Tex., and transport it to the Permian basin where it will be used in enhanced oil recovery, US Energy Secretary Steven Chu announced.

The Texas Clean Energy Project, which will be led by Summit Texas Clean Energy LLC (STCE) of Bainbridge Island, Wash., was one of three efforts receiving $979 million of federal support under the third round of DOE's Clean Coal Initiative. The other two will involve carbon capture from existing coal-fired power plants and storage in deep saline formations in West Virginia and Alabama.

"By harnessing the power of science and technology, we can reduce carbon emissions and create new clean energy jobs," Chu said Dec. 4 as he announced the funding. "This investment is part of our commitment to advancing carbon capture and storage technologies to the point that widespread, affordable deployment can begin in 8-10 years."

The award came nearly 2 years after the Midland-Odessa area lost its bid to become the site of Future Gen, the country's first fully integrated commercial power plant and CCS system, to Matoon, Ill.

STCE plans to integrate Siemens' gasification and power generating technology with carbon capture technologies to effective capture 90% of the carbon dioxide (2.7 million tonnes/year) at the planned 400-Mw plant near Midland-Odessa, DOE's Fossil Energy office said.

The captured carbon dioxide will be treated and compressed, then transported by pipeline to Permian basin oil fields in West Texas for use in EOR operations, it said. The University of Texas's Bureau of Economic Geology will design and assure compliance with a state-of-the-art sequestration monitoring, verification, and accounting program, DOE said. The project is expected to take 8 years.

A second project, led by Southern Co. Services Inc., will receive $295 million of federal funding over 11 years to retrofit $CO_2$ capture equipment on an existing Alabama Power Co. plant north of Mobile for ultimate sequestration in deep saline formations. SCS also plans to explore potentially using this captured $CO_2$ in EOR applications, DOE said.

### Sudan seeks police withdrawal from oil regions

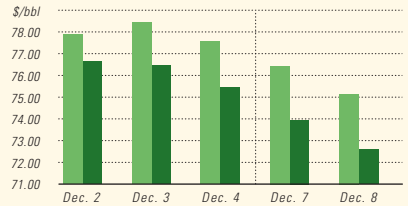
A leading member of Sudan People's Liberation Movement has called for immediate withdrawal of Sudan's national police from areas around oil fields in the southern region of the country.

Edward Lino, SPLM chairman in Abyei, told members of the group's liberation council that the presence of Sudanese national police inside Abyei territory violates the so-called Abyei road map and protocols, which aim at securing peace in the region. Lion said the road map and the protocols state that security of the region will be strictly controlled by joint integrated units [JIU] and joint integrated police units [JIPU] and not by one side alone.

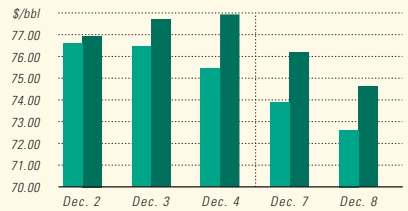
"Why are these police forces still deployed around oil installa-

# Industry Scoreboard

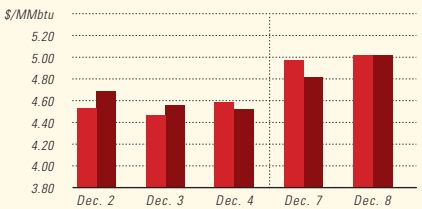
## IPE BRENT / NYMEX LIGHT SWEET CRUDE



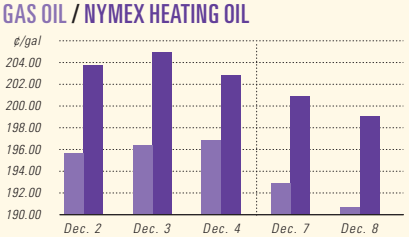

## WTI CUSHING / BRENT SPOT



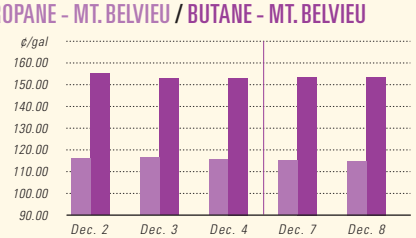

## NYMEX NATURAL GAS / SPOT GAS - HENRY HUB



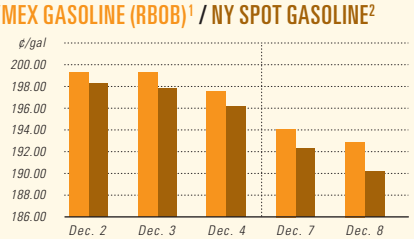

## IPE GAS OIL / NYMEX HEATING OIL




## PROPANE - MT. BELVIEU / BUTANE - MT. BELVIEU




## NYMEX GASOLINE (RBOB)[1] / NY SPOT GASOLINE[2]




[1]Reformulated gasoline blendstock for oxygen blending.
[2]Nonoxygenated regular unleaded.

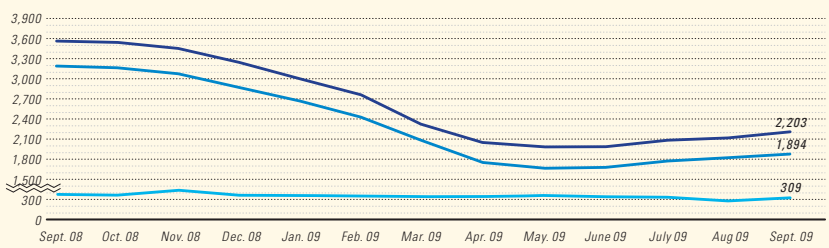
## US INDUSTRY SCOREBOARD — 12/14

| Latest week 11/27 | 4 wk. average | 4 wk. avg. year ago[1] | Change, % | YTD average[1] | YTD avg. year ago[1] | Change, % |
|---|---|---|---|---|---|---|
| *Demand, 1,000 b/d* | | | | | | |
| Motor gasoline | 8,974 | 8,913 | 0.7 | 9,024 | 8,996 | 0.3 |
| Distillate | 3,596 | 3,894 | -7.7 | 3,595 | 3,962 | -9.3 |
| Jet fuel | 1,440 | 1,438 | 0.1 | 1,413 | 1,553 | -9.0 |
| Residual | 455 | 527 | -13.7 | 537 | 611 | -12.1 |
| Other products | 4,026 | 4,326 | -6.9 | 4,081 | 4,415 | -7.6 |
| TOTAL DEMAND | 18,491 | 19,098 | -3.2 | 18,650 | 19,537 | -4.5 |
| *Supply, 1,000 b/d* | | | | | | |
| Crude production | 5,454 | 4,999 | 9.1 | 5,278 | 4,940 | 6.8 |
| NGL production[2] | 2,218 | 1,964 | 12.9 | 2,026 | 2,086 | -2.9 |
| Crude imports | 8,647 | 9,954 | -13.1 | 9,116 | 9,754 | -6.5 |
| Product imports | 2,722 | 2,950 | -7.7 | 2,761 | 3,129 | -11.8 |
| Other supply[3] | 1,453 | 1,611 | -9.8 | 1,655 | 1,579 | 4.8 |
| TOTAL SUPPLY | 20,494 | 21,478 | -4.6 | 20,836 | 21,488 | -3.0 |
| *Refining, 1,000 b/d* | | | | | | |
| Crude runs to stills | 14,341 | 14,604 | -1.8 | 14,422 | 14,676 | -1.7 |
| Input to crude stills | 14,641 | 15,120 | -3.2 | 14,762 | 15,046 | -1.9 |
| % utilization | 82.9 | 85.8 | --- | 83.6 | 85.5 | --- |

| Latest week 11/27 | Latest week | Previous week[1] | Change | Same week year ago[1] | Change | Change, % |
|---|---|---|---|---|---|---|
| *Stocks, 1,000 bbl* | | | | | | |
| Crude oil | 339,899 | 337,808 | 2,091 | 320,372 | 19,527 | 6.1 |
| Motor gasoline | 214,081 | 210,085 | 3,996 | 198,942 | 15,139 | 7.6 |
| Distillate | 165,698 | 166,868 | -1,170 | 124,973 | 40,725 | 32.6 |
| Jet fuel–kerosine | 41,820 | 42,388 | -568 | 38,567 | 3,253 | 8.4 |
| Residual | 38,056 | 36,929 | 1,127 | 37,156 | 900 | 2.4 |
| *Stock cover (days)[4]* | | | Change, % | | Change, % | |
| Crude | 24.5 | 24.3 | 0.8 | 21.9 | 11.9 | |
| Motor gasoline | 23.9 | 23.4 | 2.1 | 22.3 | 7.2 | |
| Distillate | 46.1 | 46.4 | -0.6 | 31.3 | 47.3 | |
| Propane | 44.8 | 45.3 | -1.1 | 49.2 | -8.9 | |
| *Futures prices[5]* **12/4** | | | Change | | Change | % |
| Light sweet crude ($/bbl) | 76.84 | 76.90 | -0.06 | 53.54 | 23.30 | 43.5 |
| Natural gas, $/MMbtu | 4.64 | 4.83 | -0.19 | 6.67 | -2.03 | -30.4 |

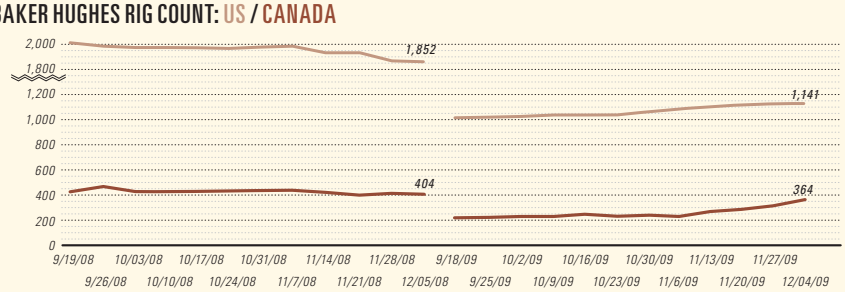
[1]Based on revised figures. [2]Includes adjustments for fuel ethanol and motor gasoline blending components. [3]Includes other hydrocarbons and alcohol, refinery processing gain, and unaccounted for crude oil. [4]Stocks divided by average daily product supplied for the prior 4 weeks. [5]Weekly average of daily closing futures prices.
Sources: Energy Information Administration, Wall Street Journal

## BAKER HUGHES INTERNATIONAL RIG COUNT: TOTAL WORLD / TOTAL ONSHORE / TOTAL OFFSHORE




Note: Monthly average count

## BAKER HUGHES RIG COUNT: US / CANADA




Note: End of week average count

tion areas?" Lino asked.

"In the light of this clear provision, I call upon the central government to immediately consider withdrawal of the national police still in Abyei territory so that security of the oil companies, their personnel and assets remains under the control of the JIUs and JIPUs," he said.

Lino's call coincided with a renewed announcement by the semiautonomous government of southern Sudan that it plans to construct a 50,000-b/d refinery in Warap state that will serve the needs of other states west of the Nile River.

The facility will require $2 billion of investment and will take 36 months to complete, said southern Sudan's Energy Minister John Luk, while Minister of Information and Broadcasting Paul Mayom Akech said oil for the refinery will be sourced Block 5A in Unity state.

Luk's announcement repeats statements he made in October, when the government of southern Sudan approved plans to build a $2 billion refinery in Akon, Warap state that would serve all seven states west of the Nile (OGJ Online, Oct. 19, 2009).

Last month, China National Petroleum Corp., apparently shrugging off environmentalists' concerns, signed three oil and gas cooperation agreements of its own with the government of Sudan.

The agreements consist of a memorandum of understanding on the second phase expansion of Khartoum refinery, advance payment for crude trading and an agreement to swap equity between CNPC's Block 6 and Malaysia State Oil's Block 5A (OGJ Online, Nov. 20, 2009). ✦

## Exploration & Development — *Quick Takes*

### Husky adds S. China Sea gas find at Liwan

A unit of Husky Energy Inc., Calgary, gauged another large gas-condensate discovery on deepwater Block 29/26 in the eastern South China Sea, near the company's 2006 Liwan discovery from which it hopes to begin gas production in 2013.

Deliverability from the LH 34-2-1 discovery could exceed 140 MMcfd of gas, similar in character to the Liwan 3-1 wells, Husky said.

LH34-2-1, in 1,145 m of water 23 km northeast of Liwan 3-1 gas-condensate field, cut a "significant thickness" of excellent quality, gas-charged reservoir, Husky said. It tested gas with a high liquids content at an equipment-restricted rate of 55 MMcfd.

Excited that its drilling program is validating the company's geological predictions in the little-drilled area, Husky noted that front-end engineering and design for the Liwan 3-1 field development, to which the LH 34-2-1 discovery will be tied in, is at an advanced stage. The company expects to submit a development plan to regulatory authorities in early 2010.

Meanwhile, the West Hercules semisubmersible is preparing to spud another exploratory well on the 551,000-acre block, and Husky plans to appraise LH 34-2 in early 2010. CNOOC Ltd. has the right to participate for up to 51% working interest in the Liwan development.

### PetroKamchatka drilling in Far East Russia

PetroKamchatka PLC, Jersey, Channel Islands, UK, is drilling its first exploration well on the Tigil block on Far East Russia's Kamchatka Peninsula and plans to begin trading this month on Canada's Toronto Stock Exchange.

Incorporated in December 2008, PetroKamchatka has secured seven onshore exploration licenses that total 8.1 million acres onshore on Kamchatka Island. It has identified numerous prospects and leads on modern 2D seismic on the Tigil and Icha blocks.

KNOC Kamchatka Petroleum Ltd., owned 55% by Korea National Oil Corp., and the Koryakia Property Fund, an investment agency of the Koryakia Okrug Administration, Kamchatka, have 50% and 5% interests, respectively, in the Tigil and Icha blocks.

PetroKamchatka, through its indirect interest in CJSC Tigil Exploration, is drilling below intermediate casing set at 1,519 m at its first well on the Tigil block.

CJSC Tigil is required to drill two wells on Tigil, one in calendar 2009 and one calendar 2010. The second well is to spud in spring 2010.

The 2010-11 work programs and budgets on the two blocks are subject to the approvals of the joint venture partner, KKPL, and PetroKamchatka's ability to obtain adequate financing.

### Kosmos confirms Odum oil find off Ghana

Kosmos Energy, private Dallas operator, confirmed its 2008 Odum discovery off Ghana, proving the potential of the Campanian play on the West Cape Three Points Block east of giant Jubilee oil field.

The company's Odum-2 appraisal well cut 66 ft of net hydrocarbon-bearing pay in high-quality stacked sandstone reservoirs over a 597-ft gross interval about 4 km northeast of the Odum-1 discovery well. The Odum discovery is 18 km east of Kosmos Energy's Mahogany-1 exploration well and Jubilee field (see map, OGJ, Dec. 8, 2008, p. 40).

Odum-2's 66 ft of net oil pay is in two intervals that appear to be in static pressure communication with the Odum-1 well, Kosmos Energy said. Odum-2 encountered an oil-water contact 190 ft below lowest known oil in Odum-1, extending the known oil column beyond the deepest oil seen in Odum-1.

Reservoir fluid samples recovered indicate the crude to be of 18-19° gravity. The Atwood Hunter semisubmersible drilled Odum-2 to 8,222 ft in 2,677 ft of water.

Odum-2 confirms the second of Kosmos Energy's four oil and gas discoveries off Ghana, where the company has drilled nine consecutive successful exploration and appraisal wells.

The Atwood Hunter will move to the adjacent Deepwater Tano Block to drill the Tweneboa-2 appraisal well that will evaluate the most recent oil find made by Kosmos Energy and partners. That group is drilling the Mahogany Deep-2 appraisal well using the Aban Abraham drillship. ✦

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# Drilling & Production — *Quick Takes*

## Aramco targets Manifa start-up in 2013

Saudi Aramco says it has finished 60% of the causeway and drilling island system and installed all offshore jackets in its shallow-water Manifa heavy-oil development project.

The project, which a company newsletter article calls "the largest single offshore crude oil project in Saudi Aramco's history," came under review when oil prices fell last year but is proceeding with start-up delayed by 2 years (OGJ, Nov. 24, 2008, Newsletter). Now scheduled on stream in 2013, the field will be able to produce 900,000 b/d of Arabian Heavy crude, 90 MMscfd of associated gas, and 65,000 b/d of condensate. Project completion is projected for 2015.

The Manifa project includes 27 man-made islands connected by 41 km of causeway in a bay that contains intensive algal habitats and dense beds of sea grass. Marine life in the bay includes pearl oysters, hamour fish, crabs, dolphins, shrimp, and sea turtles.

Aramco said it originally thought 30% of the causeway would have to be open for seawater circulation. Research determined that nearly natural circulation could be achieved with only about 10% of the causeway open, which lowered project costs.

In a Dec. 4 speech in Bangalore, India, Aramco Pres. and Chief Executive Officer Khalid A. Al-Falih said that when Aramco made the decision to develop Manifa field the price of oil was $70/bbl. After the award of initial contracts, the crude price fell to $35/bbl, but costs didn't fall proportionately, and projections for global oil demand were trimmed. "We reviewed the program, and with some execution plan modifications, including deferring completion by 2 years, decided to continue," he said.

## Colombia's Rancho Hermoso adds two new pays

Canacol Energy Ltd., Calgary, said its third and last development well of 2009 at Rancho Hermoso field in Colombia's Llanos basin found oil in two previously nonproducing formations and flowed 33° gravity oil at the rate of 3,944 b/d from one of the new pays.

Canacol Energy has 100% operated working interest in the field, and the Rancho Hermosa-5 well is in a southern extension area of the field that has remained undrilled since Colombia's state Ecopetrol discovered Rancho Hermoso in 1984.

The well found oil in Upper Cretaceous Guadalupe and Paleocene Los Cuervos in addition to Eocene Mirador, the regular field pay. TD is 9,578 ft measured depth.

RH-5 penetrated Mirador 40 ft high to prognosis. It found oil pay in Mirador at 8,939-74 ft true vertical depth with 7 ft of net interpreted oil pay thickness and average porosity of 26%, Los Cuervos at 8,990-9,020 ft with 9 ft of net interpreted oil pay thickness and average porosity of 27%, and Guadalupe at 9,037-69 ft with 24 ft of interpreted oil pay thickness and average porosity of 28%.

Guadalupe perforations at 9,042-50 ft flowed at a final rate of 3,944 b/d and 318 Mcfd of gas, natural, with water cut decreasing to 6%, on a ¾-in. choke at 145 psi bottomhole flowing pressure. The interval was tested 24 hr with rate increasing steadily throughout the test. Canacol Energy believes that the produced water is completion fluid.

Unlike production from the Mirador reservoir, for which it receives a tariff for each barrel of oil produced, production from the Guadalupe and the Los Cuervos reservoirs will bring Canacol Energy 25% of gross oil production under the terms of the production-sharing agreement with Ecopetrol.

## Libya delays plans to boost oil output

The Libyan government, hit by budget constraints and by current market conditions, has announced a delay of up to 5 years in its previously released plans to raise its oil output capacity.

"Our plan was to reach 3 million b/d by 2012, but because of the market conditions, as well as budget constraints," we delayed it to 2017, said Shokri Ghanem, chief executive officer of Libya's state-owned National Oil Corp. (NOC).

"By 2016-17, we can reach the 3 million b/d target, but we need more budget allocations," Ghanem said on the sidelines of a meeting of oil ministers of Arab countries belonging to the Organization of the Petroleum Exporting Countries. Ghanem said Libya's present production capacity is "almost 2 million b/d" and that his country is meeting its OPEC quota of 1.5 million b/d.

Meanwhile, Ghanem confirmed earlier reports that Hess Corp. has discovered "quite a big filed" of natural gas in the Gulf of Sirte, where it operates together with NOC.

According to Hess, its fully owned subsidiary Hess Libya Exploration Ltd. carried out a successful test of its discovery well A1-54/01 in the Mediterranean off Libya.

It said the A1-54/01 well was originally drilled in the Arous Al-Bahar prospect in 2008 and found hydrocarbons in several intervals with a combined gross section of about 500 ft.

Hess recently reentered and perforated the well over a 300-ft carbonate interval and performed a drill stem test.

The well flowed 27 MMscfd of "good quality" gas and 533 b/d of condensate through a 52/64-in. choke, Hess said, adding that the test was performed using the sixth-generation dynamically positioned Stena Forth drillship.

After operations on this well, Hess said the Stena Forth will return to complete the drilling of an appraisal well, A2-54/01, which lies 7 miles northwest of the discovery well.

Well A1-54/01 was drilled in 2,807 ft of water in Area 54, which is 35 miles offshore in the Sirte basin. The Hess unit holds a 100% working interest in Area 54, which it operates under an exploration and production-sharing agreement with NOC. ✦

# Processing — *Quick Takes*

## Boiler failure kills Valero refinery worker

Officials of Valero Energy Corp. and regulatory authorities are investigating the cause of what the company described as "a failure of a boiler" that killed one worker and injured two others at the company's 225,000-b/cd refinery at Texas City, Tex.

Killed by the mishap at 9 p.m. Dec. 4 was Tommy Manis, 40,

of Alvin, Tex. Injuries to the other workers were described as minor.

Valero said the refinery continued to operate. It said there was no environmental effect to the area.

### Shell pulls out of Chinese refinery plans

Royal Dutch Shell PLC reported last week it has withdrawn from talks with China Petroleum & Chemical Corp. (Sinopec) and Kuwait Petroleum Corp. that were to lead to construction of a $9 billion, 300,000-b/d refinery in China's Guongdong province.

A Shell spokesperson told OGJ that, due to "strategic and commercial considerations, Shell has decided not to pursue the downstream opportunity currently in discussion between KPC and Sinopec."

Regional media speculation agreed that the move opens the way for other international oil companies to join the joint venture. In its quoted comments, Sinopec made clear it would retain a 50% interest, leaving any other party to carve out a stake from KPC's 50% interest.

Shell is seen as pulling away from new downstream ventures in favor of more oil and natural gas exploration and production.

A memorandum of understanding is in force between state-run KPC and Sinopec to build the refinery and petrochemical complex that will produce 1 million tonnes/year of ethylene. Kuwait is to supply all the oil for the project.

Chinese government approval for the project is expected in first-quarter 2010.

### Kupe gas project off New Zealand starts up

Origin Energy New Zealand Ltd. has begun commissioning the offshore Kupe field with initial production, moving natural gas and liquids ashore via pipeline to a gas processing plant at Hawera (see map, OGJ, July 16, 2001, p. 38).

Full start-up is likely within 2 months, said Andrew Stock, Origin's executive general manager of major development projects.

Kupe gas project participants are Origin (50%, operator), a wholly owned subsidiary of Origin Energy Ltd.; Genesis Energy (31%); New Zealand Oil & Gas Ltd. (15%); and Mitsui E&P Australia Pty. Ltd. (4%)

Paul Zealand, Origin executive general manager of upstream oil and gas, said once Kupe was in full operations, it would provide 10-15%/year of the country's gas demand for 15-20 years. Kupe will produce up to 90,000 tonnes/year of LPG, more than 50% of the country's demand, he said.

Over the project life, Kupe is expected to provide 6.6 billion cu m of gas, 1.1 million tonnes of LPG, and 14.7 million bbl of light crude. ✦

## Transportation — *Quick Takes*

### Two more firms join Santos basin LNG scheme

Repsol YPF SA and Galp Energia have joined Petroleo Brasileiro SA (Petrobras) and BG Group to develop front-end engineering and design for the construction of an onboard natural gas liquefaction unit that will operate 300 km off Brazil. The planned site is on Blocks BM-S-9 and BM-S-11 in Santos basin's presalt pole.

The unit is one of the transportation technologies being considered to flow gas produced in the presalt layers, according to Petrobras.

Stakes in the expanded joint venture are now Petrobras holding 51.1%, while BG, Repsol YPF, and Galp each hold 16.3% interests. The JV partners also are partners in Blocks BM-S-9 (Petrobras, BG, and Repsol YPF) and BM-S-11 (Petrobras, BG, and Galp).

The tender for preparation of the FEED for the unit was started last August (OGJ Online, Nov. 18, 2009). Planned installation of the unit will be near the floating oil and gas production units and receive, process, and liquefy as much as 14 million cu m/day of associated gas.

Petrobras also said the unit will store and transfer processed products (LNG, propane, and butane) to vessels, which, in turn, will then transport them to market. The LNG, the company said, will be delivered to regasification terminals, which will vaporize it and inject it into the gas pipeline network.

Petrobras operates LNG regasification terminals in Brazil: in Pecem, state of Ceara, and in the Guanabara Bay, state of Rio de Janeiro (OGJ, July 27, 2009, p. 33).

Petrobras said the unit will allow Santos basin's presalt pole gas reserves to be monetized, "ensuring flexibility to supply the internal market and the possibility of exporting the product in the spot market" when demand in the Brazilian thermoelectric segment is low.

### Chevron signs deal for Wheatstone project

Chevron Australia has signed an offtake agreement with Tokyo Electric Power Co. (Tepco) to sell 4.1 million tonnes/year of LNG from the Wheatstone project over a 20-year term.

The heads of agreement is believed to be worth about $90 billion (Aus.).

In addition, Tepco is planning to acquire a 15% interest in the Wheatstone field licenses along with an 11.25% interest in the proposed gas processing facilities planned for Ashburton North near Onslow on the Western Australian coast.

Western Australian Premier Colin Barnett hailed the agreement by noting that his State will benefit from significant new export earnings and from an additional 200 terajoules of domestic gas, which is part of the project program.

Barnett said the Wheatstone project also would bring new development to Onslow in the form of a deepwater port and the establishment of an 8,000 hectare strategic industrial park at the Ashburton North site.

The initial stage for Wheatstone will have a capacity to produce 8.6 million tonnes/year of LNG and will also include the domestic gas plant.

Chevron expects to make a final investment decision on the project in 2011. ✦

# Letters

## Climate feedbacks

Regarding the editorial "Climate change twists", you refer to the assumption by climate change alarmists that there is a positive feedback magnifying the minuscule direct effect of additional carbon dioxide in the atmosphere (OGJ, Nov. 2, 2009, p. 18). However, data trump assumptions and the data show a negative feedback, not the assumed positive feedback (see "Climate Feedback" by Lindzen and Choi, Geophysical Research Letters 36, L161705, Aug. 26, 2009).

Other information plus common sense tells us that nature, not human activity, controls climate. There has been an increase in temperature as the earth recovers from the Little Ice Age. The warmest year during this period was 1934, well before our use of fossil fuels took off, about 1950. Superimposed on the long-term warming period there have been shorter-term warming and cooling periods which are correlated with the activity of the sun.

Before the Little Ice Age, there was a medieval warm period, warmer than today. It was a good time for human beings, without catastrophic climate effects.

The argument that carbon dioxide intensified Katrina doesn't hold water. While carbon dioxide concentration continues to increase, there have been no serious hurricanes reaching the US this season. A simplistic look at this fact could lead to an argument that carbon dioxide protects us from hurricanes.

*William E. Morris*
*Wilmington, Del.*

# Calendar

✦ Denotes new listing or a change in previously published information.

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PIRA Understanding Natural Gas and LNG Markets Seminar, New York, (212) 686-6808, (212) 686-6628 (fax), website: www.pira.com. 14-15.

PIRA Understanding Global Oil Markets Seminar, New York, (212) 686-6808, (212) 686-6628 (fax), website: www.pira.com. 16-17.

## 2010

## JANUARY

Plant Maintenance in the Middle East & Annual Meeting, Abu Dhabi, +44 (0) 1242 529 090, +44 (0) 1242 529 060 (fax), e-mail: wra@theenergyexchange.co.uk, website: www.wraconferences.com. 10-13.

Oil & Gas Maintenance Technology Conference & Exhibition Co-located with Pipeline Rehabilitation and Maintenance, Manama, Bahrain, (918) 831-9160, (918) 831-9161 (fax), e-mail: registration@pennwell.com, website: www.oilandgasmaintenance.com. 18-20.

Pipeline Rehabilitation & Maintenance Co-located with Oil & Gas Maintenance Technology, Manama, Bahrain, (918) 831-9160, (918) 831-9161 (fax), e-mail: registration@pennwell.com, website: www.pipeline-rehab.com. 18-20.

World Future Energy Summit, Abu Dhabi, +971 2 4090 445, +971 2 444 3768 (fax), e-mail: ludoiva.sarram@reedexpo.ae, website: www.worldfutureenergysummit.com. 18-21.

Global Floating LNG Summit, London, +44 0 207 368 9300, e-mail: enquire@iqpc.co.uk, website: www.global-flngsummit.com. 20-21.

SPE Oil and Gas India Conference and Exhibition, Mumbai, (972) 952-9393, (972) 952-9435 (fax), e-mail: spedal@spe.org, website: www.spe.org. 20-22.

SPE Deep Gas Conference, Manama, (972) 952-9393, (972) 952-9435 (fax), e-mail: spedal@spe.org, website: www.spe.org. 24-27.

API Exploration and Production Winter Standards Meeting, New Orleans, (202) 682-8000, (202) 682-8222, website: www.api.org. 25-29.

Health, Safety, Environment & Training Conference & Exhibition, Houston, (713) 292 1945, (713) 292 1946 (fax), e-mail: info@iadc.org, website: www.iadc.org. 26-27.

The European Gas Conference and Annual Meeting, Vienna, +44 (0) 20 7067 1800, +44 (0) 20 7242 2673 (fax), website: www.theenergyexchange.co.uk. 26-28.

API/AGA Joint Committee on Oil and Gas Pipeline Welding Practices Conference, New Orleans, (202) 682-8000, (202) 682-8222 (fax), website: www.api.org. 27-29.

Annual Gas Arabia Summit, Abu Dhabi, +44 (0) 20 7067 1800, +44 (0) 20 7242 2673 (fax), website: www.theenergyexchange.co.uk. Jan. 31- Feb. 3.

International Process Analytical Technology Forum (IFPAC), Baltimore, (847) 543-6800, (847) 548-1811 (fax), e-mail: info@ifpacnet.org, website: www.ifpac.com. Jan 31-Feb 4.

## FEBRUARY

Deep Offshore Technology International Conference & Exhibition, Houston, (713) 963-6271, (713) 963 6296 (fax), e-mail: registration@pennwell.com, website: www.dotinternational.net. 2-4.

IADC/SPE Drilling Conference and Exhibition, New Orleans, (713) 292 1945, (713) 292 1946 (fax), e-mail: info@.org, website: www.iadc.org. 2-4.

Russia Offshore Annual Meeting, Moscow, +44 (0) 20 7067 1800, +44 (0) 20 7242 2673 (fax), website: www.theenergyexchange.co.uk. 2-4.

Global Petrochemicals Conference & Annual Meeting, Vienna, Austria, +44 (0) 1242 529 090. +44 (0) 1242 529 060 (fax), e-mail: wra@theenergyexchange.co.uk, website: www.wraconferences.com. 9-11.

SPE International Symposium & Exhibition of Formation Damage Control, Lafayette, (972) 952-9393, (972) 952-9435 (fax), e-mail: spedal@spe.org, website: www.spe.org. 10-12.

NAPE Expo, Houston, (817) 847-7701, (817) 847-7703 (fax), e-mail: info@napeexpo.com, website: www.napeonline.com. Feb 11-12.

Annual Petroleum Coke Conference, Seattle, (832) 351-7828, (832) 351-7887 (fax), e-mail: petcoke.conference@jacobs.com, website: www.petcokes.com. 12-13.

SPE North Africa Technical Conference & Exhibition, Cairo, (972) 952-9393, (972) 952-9435 (fax), e-mail: spedal@spe.org, website: www.spe.org. 14-17.

IP Week, London, +44 0 20 7467 7132, +44 0 20 7255 1472 (fax), e-mail: jbia@energyinst.org.uk, website: www.energyinst.org.uk. 15-18.

Pipeline Pigging & Integrity Management Conference & Exhibition, Houston, (713) 521-5929, (713) 521-9255 (fax), e-mail: clarion@clarion.org, website: www.clarion.org. 16-18.

Pipe Line Contractors Association Annual Conference (PLCA), Scottsdale, Ariz. (214) 969-2700, e-mail: plca@plca.org, website: www.plca.org. 17-21.

# EPA upstages conference

Sam Fletcher
Senior Writer

The Environmental Protection Agency upstaged the opening of the Copenhagen climate conference by formalizing on Dec. 7 its finding that carbon dioxide—the fifth most common gas in the Earth's atmosphere—is a "pollutant" that threatens life on this planet through global warming.

EPA's decision was generally expected following its preliminary finding against the gas in April as the result of a study it undertook after the 2007 US Supreme Court ruling that greenhouse gases (GHG)—including $CO_2$—are within the federal Clean Air Act's definition of pollutants. That opens the way for the EPA to regulate $CO_2$ emissions under the Clean Air Act. "In practical terms, though, the EPA isn't about to start regulating carbon. And if it tries to do that without Congressional backing, expect a flood of litigation," said analysts in the Houston office of Raymond James & Associates Inc.

Like many skeptics, Raymond James analysts suspect the timing of the EPA's announcement was "designed as a way for President [Barrack] Obama to claim credit for something when he goes to Copenhagen" to speak at the climate conference. "Since the Waxman-Markey bill is not going anywhere in the Senate, the EPA ruling is probably the only source of leverage he can bring with him to the negotiating table," they said.

Obama originally was scheduled to deliver a tone-setting speech at the conference in a quick stopover Dec. 9 on his way to Oslo to pick up his Nobel Prize. However, his appearance at the conference was pushed back to the Dec. 18 closing when 65 other heads of state and government are expected to attend. The White House said the visit was rescheduled after recent pledges by China and India to reduce GHG emissions.

Proponents hope it will give Obama the opportunity to charm other heads of state into some climate agreement. But several energy analysts remained skeptical that any major agreement will result from the meeting.

## 'Back-stabbing' reported

Summit "security is apparently so tight that it took 2 full days before the member states stabbed each other in the back," Raymond James analysts reported Dec. 9. "That, at least, is how developing countries perceive the draft text of the agreement, leaked yesterday by a group of key negotiators," they said. "In a nutshell, the draft is more favorable to industrialized countries in several respects. It would require developing countries to agree to binding emissions cuts, which they adamantly reject. Also, it would give more power over climate-related development aid to the World Bank (which is dominated by the West) as opposed to the UN."

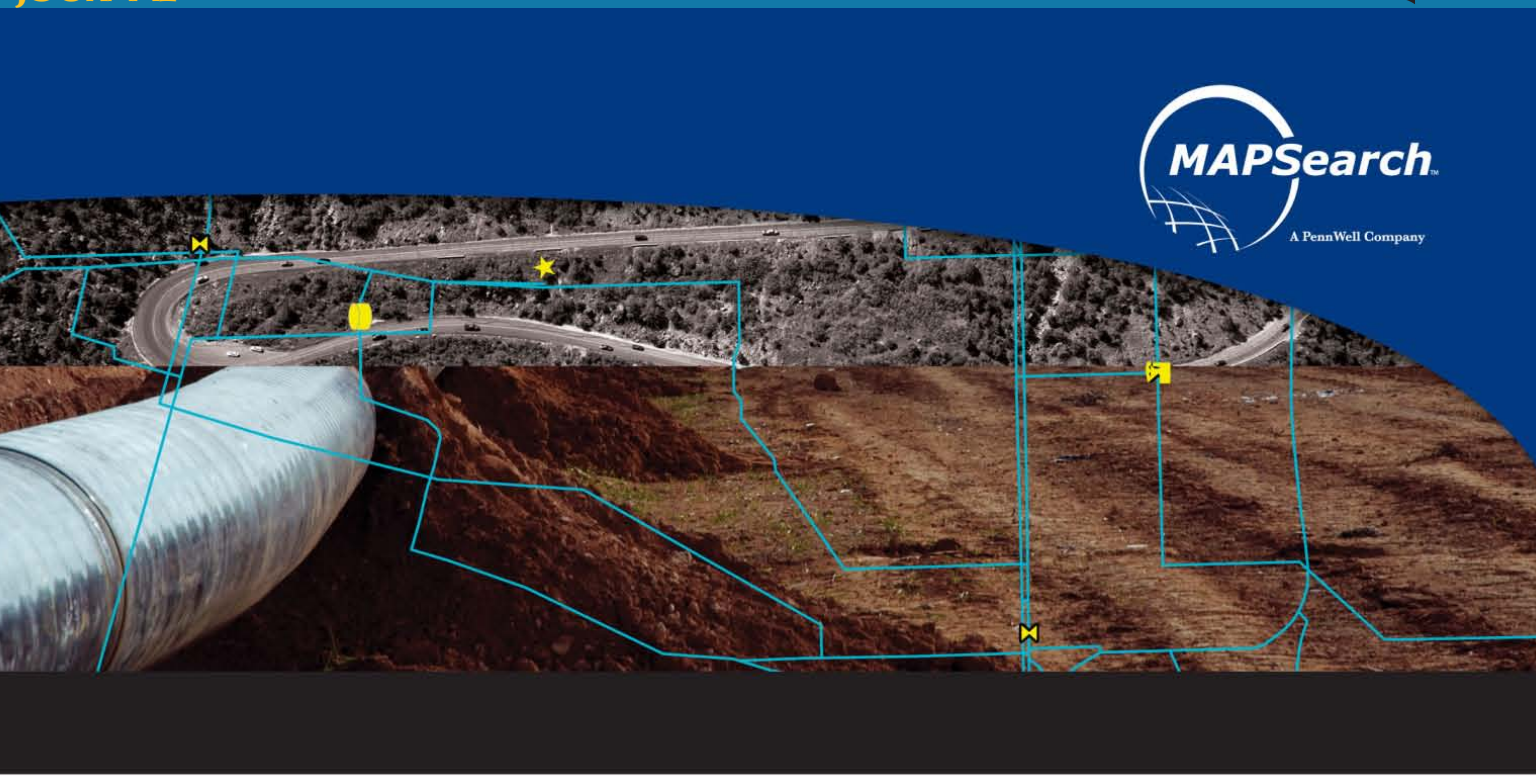
They claimed there is "no way" China and India will sign such an agreement, "which means the final text—assuming there will even be one—will have to look very different."

Analysts at FBR Capital Markets & Co. in Arlington, Va., said, "US-China competitiveness will continue to be the defining factor. One key to moving legislation in the Senate is the extent to which China and India appear ready to take on binding, absolute emissions caps in coordination with US reductions (rather than intensity reductions)."

Obama earlier proposed a 17% US reduction in GHG and $7-10 billion in mitigation funding for developing nations. But any agreement reached at Copenhagen "will be contingent on Congress passing climate legislation," FBR analysts said. Congress also controls funding mechanisms. "Thus, we caution investors against over-interpreting positive signals coming from the Copenhagen conference. The fundamental barriers to passing climate change in the Senate will remain unaltered by international diplomacy," said FBR analysts.

According to the Fundamentals of Physical Geography, 2nd Edition, $CO_2$ increased more than 35% in the last 300 years, yet is still classed as a trace gas, comprising only 0.036% of our atmosphere. By comparison, methane—another GHG—increased more than 150% since 1750. At 0.00017%, it is the eighth most common gas; its primary sources include in order of importance, rice cultivation, domestic grazing animals, termites, landfills, coal mining, and oil and gas extraction. It's hard to say how much methane is produced from rice paddies since 60% are in India and China where scientific data on emission rates are unavailable.

The biggest GHG component, of course, is water vapor, which is 4% of the earth's atmosphere up to an altitude of 25 km. The only thing coming out the tailpipes of some of the new alternative-fuel cars is more water vapor. ✦

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Editorial

# Deconstructing endangerment

With the US Environmental Protection Agency's "endangerment finding" on greenhouse-gas emissions (GHGs), the politics of global warming reveals its tyrannical core.

EPA obviously scheduled its Dec. 7 announcement for maximum coercive effect. International leaders were meeting in Copenhagen to negotiate an agreement to follow the Kyoto Treaty. And the US Senate had delayed into 2010 its work on legislation to limit GHG emissions. By assuming responsibility for GHG regulation, the EPA scored diplomatic points in Denmark and raised pressure on Congress.

## Seizing control

It also seized control of energy consumption, business practice, and thus much of American life. Nothing in the politics of climate change is more important than shifts, such as this, of economic choice from people to state. When EPA declared GHGs threaten public health and therefore should be regulated under the Clean Air Act (CAA), it wasn't just leveraging current affairs. It was grabbing power.

A juridical response is certain; the Competitive Enterprise Institute promises a lawsuit. Others will follow. And a political backlash is inevitable—if not now, when the power transfer remains conceptual, then later, as freedoms shrink and costs bite.

Deconstruction of this unfinished history is in order. Logically and legally, EPA could not have decided by itself that CAA authorizes it to regulate GHGs. The CAA addresses air pollutants, substances known to degrade human health. The GHG for which humanity is most responsible, carbon dioxide, doesn't fit the description. It's essential to life. It degrades human health only if it intensifies natural greenhouse warming dangerously—and then not for many years. The proposition that it does so is controversial. Seeing a reason to treat $CO_2$ the same as ground-level ozone and airborne toxics requires expansive reading of the CAA.

But the Supreme Court made such a reading in 2007. In a decision related to legal language rather than science, the court said EPA could regulate $CO_2$ and other GHGs under CAA if it determined they endangered people. EPA now has made the determination and claimed the authority.

The case on which the high court ruled wouldn't have been filed if no one feared that a buildup of GHGs in the atmosphere threatened the planet with disastrous warming. But the fear is widespread. It results from relentless propagation of the message that observed warming is unprecedented and destined to become extreme, that it comes mainly from human activity, and that humans need to change behavior radically to prevent catastrophe.

That message grounds itself in predictions of computer models developed by the Intergovernmental Panel on Climate Change, a large group of scientists working under auspices of the United Nations. The IPCC published the discredited "hockey-stick" graph that was supposed to have shown how global average temperature leaped along with use of fossil energy after centuries of little change. The IPCC famously declared that people bear responsibility for most recent warming. And the IPCC embodies the "consensus of scientists" adduced in support of the activist climate agenda.

While the IPCC's work is important, it's not the whole of climate science. Its reliance on computer models, sophisticated as they are, has come under question as climate observations stray from model predictions. Also questioned is IPCC's focus on an imperfect correlation between GHG emissions and apparent warming; some scientists think natural factors, such as variation in solar intensity, have stronger influence.

## Political armor

Shots at IPCC findings, however, have tended to ricochet off the group's heavy political armor—until recently. Data fundamental to IPCC conclusions come from the Climate Research Unit at East Anglia University in the UK. Last month, e-mails stolen or leaked from the university's servers showed scientists, some of them political celebrities, destroying or manipulating data and scheming to delegitimize contradictory science.

So a federal agency has extended its regulatory reach under authority of a court ruling in a lawsuit flowing from a belief grounded in work of a politically grounded group the scientific soundness of which has become doubtful. As the basis for a major expansion of government, this chain is far too brittle. ✦

# Canada looks to shales for boost to gas supply

Natural gas from shale formations represents a potentially crucial source of supply growth in Canada, where production from conventional reservoirs is declining in a trend likely to continue.

While two shale gas plays—in the Horn River basin straddling the boundary between northern British Columbia and Alberta and the Triassic Montney shale to the south—draw most of the current drilling, potential exists elsewhere in the country. In some of the newer plays, drilling has just begun.

Production of gas from shale isn't new to Canada. The National Energy Board, for example, points out that the Cretaceous Second White Speckled shale of southern Alberta and Saskatchewan has produced gas for decades. But that shale is fractured enough naturally to produce gas commercially through vertical wells without the sophisticated fracturing and horizontal wells essential to most of the burgeoning new shale developments of North America.


In the more challenging shales capturing new industry attention, Canadian development lags that of the US. Canadian Society for Unconventional Gas (CSUG) Pres. Michael Dawson, in a September presentation, arrayed North American shale gas plays along a scale of development progress. Among Canadian plays, only the hybrid Montney—in some areas a tight sand because of its high silt and silica content—had reached what he described as the commercial stage. The US plays he judged to be at that stage were the Marcellus, Barnett, Haynesville, Fayetteville, and Woodford shales.

Speaking at the National Bank Financial Energy Services Conference, Dawson assigned the Horn River basin play in part to the pilot production-testing phase, where it aligned with newer projects in the Marcellus shale, and in part to the pilot-project drilling stage, aligned with the Eagle Ford play in the US.

Shales in the Quebec lowlands, Nova Scotia, and New Brunswick, Dawson said, remain at a stage he described as early evaluation drilling.

As in the US, shales in Canada differ greatly—shale versus shale and location versus location within a single shale—and require tailored completions and various fracturing methods. According to Dawson, Canadian shale plays have economics less favorable than many of the unconventional gas plays of the US.

## Crucial supply

But their development is crucial to Canadian gas supply.

In a November outlook, the Canadian Association of Petroleum Producers documented declines during the past several years in Canadian drilling and gas production in Alberta (Fig. 1). CAPP sees gas from tight formations and shales in British Columbia as the most important element of an expected recovery and eventual expansion of gas production through 2020 (Fig. 2).

Now, however, shale gas production

isn't rising fast enough to offset declines from conventional reservoirs, where economics have soured.

"Massive value destruction is occurring for the shareholder, or unit holder, for each thousand cubic foot of gas produced today," said Paul Ziff, chief executive officer of Ziff Energy Group, in a June report.

His reason: Gas prices aren't high enough to cover the costs of replacing produced reserves in the conventional reservoirs of western Canada.

A 2008 study by his group showed that the reserves life of gas reserves in the region had declined from more than 20 years to less than 9 years, a level requiring 12%/year reserves replacement.

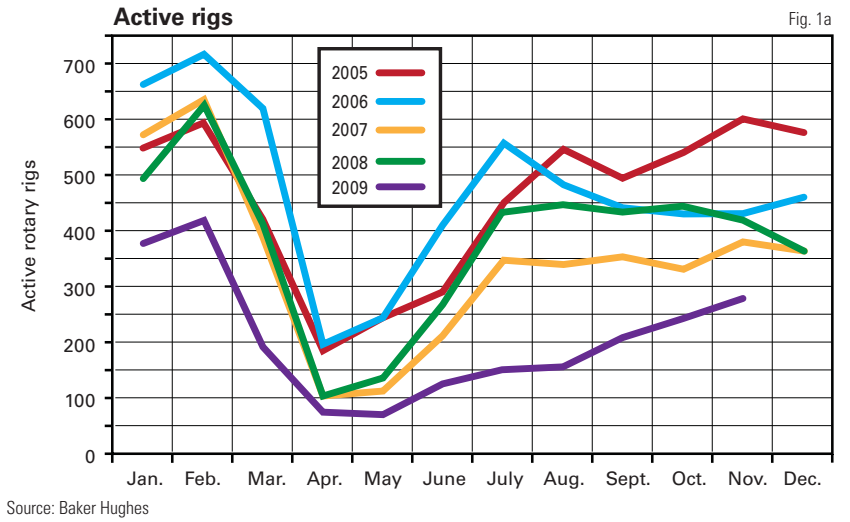
The gas price when he spoke was about $3/Mcf (Can.), which according to his analysis generated a loss of $3.40/Mcf after cash operating costs of $2.30/Mcf, 60¢/Mcf for general and administrative expenses and interest payments, and $3.50/Mcf for drilling, depletion, and amortization. Ziff estimated full-cycle costs for gas production at $8/Mcf.

"Core gas reserves are being sold/depleted at market prices that simply cannot be replaced by the cash generated," he said. "So producers' reserve base shrinks, and in the near future more equity or debt will need to be issued to fund replacing the gas produced today."

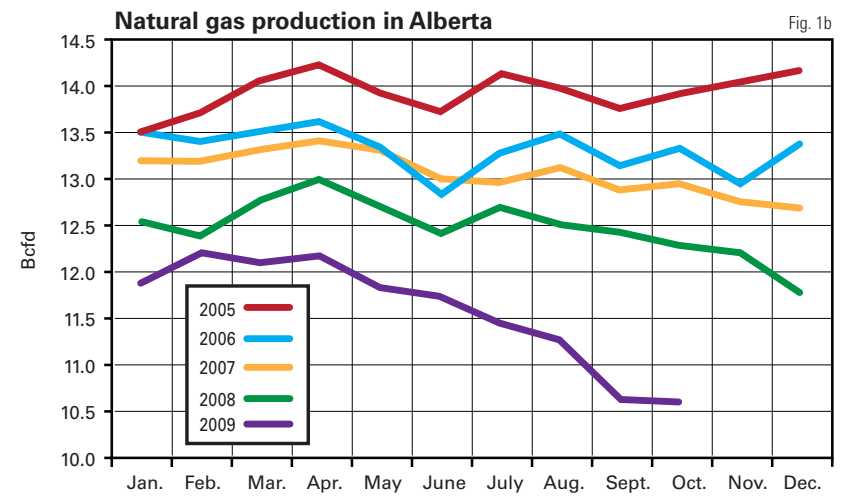
Unconventional gas—from tight formations, coalbeds, and shale—"is moderating the western Canada decline but not reversing it," Ziff said.

## Canadian drilling, gas production

Fig. 1




Source: Baker Hughes




Source: Canadian Association of Petroleum Producers from FirstEnergy Capital data

## Well characteristics

The NEB assessed Canada's shale gas potential in a comprehensive review last month. It said total volumes of recoverable gas are expected to be 1-10 bcf from each horizontal well drilled into Canadian gas shales, with amounts likely to grow as technology improves.

Initial production rates from horizontal shale gas wells are high—generally 3-16 MMcfd. But production tends to decline rapidly in each well's first year before flatting into a gradual decline. Horizontal shale gas wells, NEB said, are expected to produce for more than a decade each.

Vertical wells in silica-rich gas shales have initial production rates around 1 MMcfd. In the shallow Middle Cretaceous Colorado shale, initial production rates are less than 100 Mcfd.

NEB said the average Canadian conventional gas well drilled and placed on production in 2007 initially flowed about 200 Mcfd.

In the Montney formation, horizontal wells cost $5-8 million each, while Horn River basin wells cost as much as $10 million. Wells in the Upper Ordovician Utica shale are expected to cost $5-9 million.

Vertical wells into shallow shales with gas of biogenic origin, such as the Colorado shale, cost less than $350,000 each.

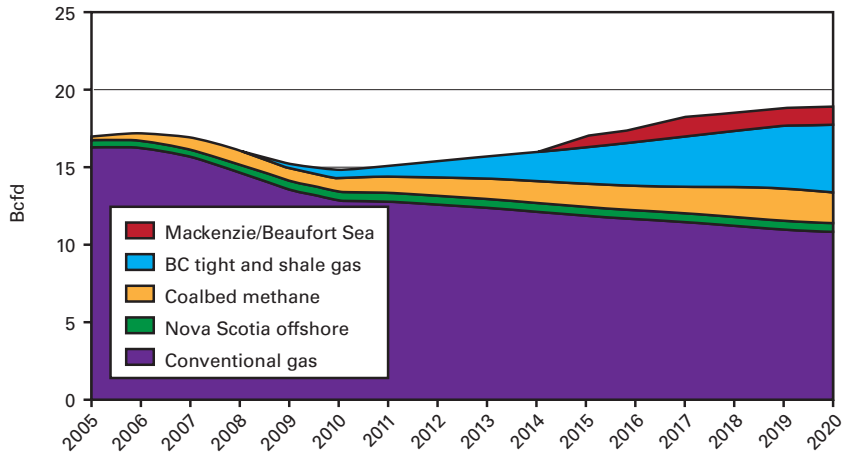
## Surface work

In British Columbia, gas production beyond what's expected to be reached within just a few years will require expansion of surface facilities. The NEB's November review highlighted several projects planned to relieve the bottlenecks.

Spectra Energy is considering expansion of its gas processing plant at Fort

## CAPP'S OUTLOOK FOR CANADIAN GAS PRODUCTION

Fig. 2




Source: Canadian Association of Petroleum Producers

Nelson in the southern Horn River basin. About half the existing inlet capacity of 1 bcfd is in use at present; the expansion would add 250 Mcfd at facilities 40 km northeast of Fort Nelson at Cabin Lake.

EnCana Corp. has proposed construction in six stages of 2.4 bcfd of gas processing capacity at Cabin Lake.

The NEB report mentioned Spectra Energy's construction of 92.7 km of 20-in. pipeline extending the company's raw-gas gathering system in the Fort St. John area to an area south of its 680 MMcfd McMahon gas processing plant in Taylor, BC.

Also in British Columbia, NEB noted, Nova Gas Transmission Ltd. proposes a 1 bcfd pipeline extending the company's Alberta System into the shale gas producing area. Nova says the 77-km, 36-in. Groundbirch Mainline Project would run between points 12 km west of Gordondale, Alta., and 4 km northwest of Groundbirch, BC.

NEB said several years might pass before production of gas from shale warrants construction of large-scale short-haul pipeline capacity. It said expansion of major long-haul pipeline capacity from western capacity is less likely to be needed because of pipeline capacity becoming available as conventional production declines.

Prospective shale gas plays elsewhere in Canada are closer to existing pipelines.

The Utica play is near the Trans Quebec & Maritimes Pipeline serving Montreal and Quebec City with connections to pipelines serving the Northeast US. The system has spare capacity.

And the Horton Bluff shale play in New Brunswick and Nova Scotia is close to the Maritimes & Northeast Pipeline system.

### Prospective shales

In its report, NEB described the main shale gas plays under development or study in Canada. It pointed out that the characteristics summarized in Table 1 come from various sources and present data it didn't try to verify.

The table indicates potential for 1 quadrillion tcf of gas in place, somewhat less than the total of estimates by the CSUG shown in Fig. 3. "How much of that gas can be recovered still needs to be confirmed," NEB said. "Initial estimates are about 20%."

Summaries of its shale descriptions follow.

- The ***Montney*** formation produces from conventional shallow-water shoreface sandstones on its eastern edge and from deepwater tight sands at the foot of the depositional ramp to the west. Hybrid gas potential exists in the Lower Montney, involving sandy, silty shales of the offshore transition and offshore-marine parts of the basin, and the Upper Montney, below the shoreface where silts buried the tight sands at the foot of the ramp.

Because the Montney is more than 300 m thick in places, operators are planning stacked horizontal wells, drilling and fracing laterals in both the Upper and Lower Montney.

Estimates for the Montney formation exclude the overlying Triassic Doig phosphate, which also has shale gas potential.

Citing British

## A NATIONAL ENERGY BOARD REVIEW OF CANADIAN GAS SHALES

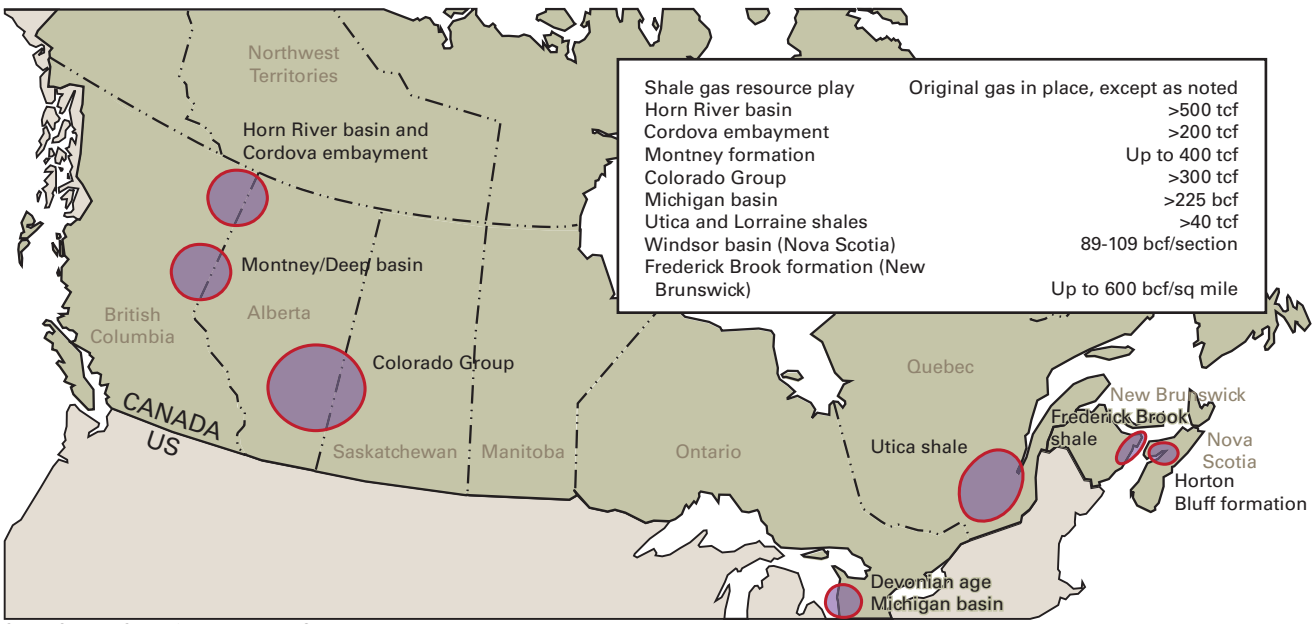
Table 1

| | Horn River | Montney | Colorado | Utica | Horton Bluff |
|---|---|---|---|---|---|
| Depth (m) | 2,500-3,000 | 1,700-4,000 | 300 | 500-3,300 | 1,120-2,000+ |
| Thickness (m) | 150 | Up to 300 | 17-350 | 90-300 | 150+ |
| Gas-filled porosity (%) | 3.2-6.2 | 1.0-6.0 | Less than 10 | 2.2-3.7 | 2 |
| Total organic carbon (%) | 0.5-6.0 | 1-7 | 0.5-12 | 2.2-3.7 | 10 |
| Maturity ($R_o$) | 2.2-2.8 | 0.8-2.5 | Biogenic | 1.1-4 | 1.53-2.03 |
| Silica (%) | 44-65 | 20-60 | Sand and silt | 5-25 | 38 |
| Calcite or dolomite (%) | 0-14 | Up to 20% | — | 30-70 | Significant |
| Clay (%) | 20-40 | Less than 30 | High | 8-40 | 42 |
| Free gas (%) | 66 | 64-80 | — | 50-65 | — |
| Adsorbed gas (%) | 34 | 20-36 | — | 35-50 | — |
| $CO_2$ (%) | 12 | 1 | — | Less than 1 | 5 |
| Gas in place/section* (bcf) | 60-318+ | 8-160 | 22-62 | 25-210 | 72.4-600+ |
| Play area gas in place (tcf) | 144-600+ | 80-700 | >100 | >120 | >130 |
| Horizontal well cost, including frac (million Can. $) | 7-10 | 5-8 | 0.35 (vertical only) | 5-9 | Unknown |

*In western Canada, a section is 1 sq mile.
Source: National Energy Board compilation from various sources

## A LOOK AT CANADA'S GAS SHALE PROSPECTS

Fig. 3




Source: Canadian Society for Unconventional Gas

Columbian data, NEB said operators had spent $2.4 billion for Montney gas rights in government auctions in 2005-08, $1.3 billion in 2008 alone.

As of last July, NEB said, 234 horizontal wells were producing 376 MMcfd from the Montney shale, mostly from the Heritage pool of British Columbia.

Individual wells produce 3-5 MMcfd generally, occasionally more than 10 MMcfd, at start-up, followed by rapid declines. The wells usually have 7 to 9 and as many as 12 100-tonne carbon dioxide or water frac stages over 2-km horizontal legs.

• In the ***Horn River basin***, shales rich in silica lie at the foot of the Devonian Slave Point carbonate platform, which has long produced gas from conventional reservoirs. Operators have drilled, hydraulically fractured, and placed on production about 20 horizontal Horn River wells.

Before starting their steep declines, wells in the area produce at start-up at rates as high as 16 MMcfd. Production data in the Horn River basin remain confidential.

Associated with the Horn River basin play and to the east is the ***Cordova embayment***, which has an estimated 200 tcf of gas in place but remains at a much earlier stage of evaluation.

NEB said that as of May operators had spent more than $2 billion in British Columbia government auctions for resource rights in the Horn River basin and less than $40 million in the Cordova embayment.

• The ***Colorado Group*** comprises shaley strata deposited in southern Alberta and Saskatchewan in the Middle Cretaceous. It includes the Medicine Hat and Milk River shaley sandstones, which have produced gas for more than 100 years, and the Second White Speckled shale.

Colorado Group shale, like the Montney, is a hybrid, producing through thin sand beds and laminae. It's underpressured, sensitive to water, and therefore difficult to frac. Operators are testing the use of nitrogen and mixtures of propane and butane as frac fluid.

More than 3 MMcfd is flowing from "a few dozen" shallow vertical wells in the Wildmere area of Alberta, where the Colorado shale is about 200 m thick and has potential to produce from five intervals. Wells cost $350,000 each from drilling through connection with pipelines.

Noting the difficulty of estimation given the shale's great lateral extent and reservoir variability, NEB said the Colorado Group might hold at least 1 tcf of gas in place.

• The ***Utica shale*** was deposited in deep waters at the foot of the Trenton carbonate platform. Caught later in early Appalachian Mountain growth, it became faulted and folded to the southeast. It's the source rock for conventional oil reservoirs.

The Utica shale has higher concentrations of calcite, which is less brittle than the silica it displaces, than other Canadian gas shales. It contains biogenic gas in shallow areas and thermogenic gas at greater depths.

Vertical wells after fracing in the Utica shale are reported to have produced 1 MMcfd of gas. Three hydraulically fraced horizontal wells are reported to have tested 100-800 Mcfd of gas from medium-deep shales.

The overlying Lorraine shale might have potential but is richer in clay and therefore difficult to frac.

• In the Canadian Maritimes, the ***Horton Bluff Group*** contains lacustrine

muds deposited during regional Early Mississippian subsidence.

The average silica content of the group's **Frederick Brook shale** is 38% in New Brunswick, but the clay content also is high at 42%. In Nova Scotia, the Frederick Brook member has an organic content of 10%, much higher than other Canadian gas shales.

Frederick Brook thickness may be greater than 150 m, NEB said, sometimes exceeding 1 km in New Brunswick. Flow testing is in progress. Although hydraulic fracing has been less successful than in western Canada, two vertical Frederick Brook wells in New Brunswick have flowed 150 Mcfd after small fracs.

Corridor Resources has estimated that the Frederick Brook shale of the Sussex and Elgin subbasins of southern New Brunswick holds 67 tcf of free gas in place. Ryder Scott Co. has estimated 69 tcf of gas in place on the Windsor Block in Nova Scotia. Samples in Nova Scotia indicate most of the gas is adsorbed onto clay and organic matter, requiring effective stimulation.

Apache Canada, a large Horn River basin participant, recently joined Corridor in the Frederick Brook play (OGJ Online, Dec. 8, 2009).

### The future

The NEB said shale gas "may be a key component that will allow Canada to sustain its own domestic requirements for natural gas far into the 21st Century," supplemented, perhaps, by other resource plays such as coalbed methane and tight sandstones and carbonates and by future production from frontiers offshore and in the north.

Shale gas might even allow Canada to export LNG, NEB said, citing memorandums of understanding signed by Horn River basin operators Apache Corp. and EOG Resources to supply a proposed liquefaction plant in British Columbia.

But the play overall remains young. "Only the Montney and Horn River basin gas shales can be said to have 'proof of concept' through numerous production tests after horizontal drilling and hydraulic fracturing," NEB said. And only the Montney is producing at significant rates.

Economic uncertainties remain. And concerns have arisen about environmental effects, especially water requirements and carbon dioxide emissions, although proposals have come forward for carbon capture and sequestration projects.

Furthermore, the pace of development may be limited by supply of required resources, such as fresh water, fracture proppant, or drilling rigs.

The play is still in early stages. But the potential boost to Canadian gas supply is great. ✦

# IEA forecast includes climate-change policy scenario

**Nick Snow**
*Washington Editor*

The International Energy Agency developed a climate-change policy scenario as part of its latest annual forecast because it wanted "to be part of the solution as well as part of the problem," a top official said on Dec. 2.

"Sixty percent of the world's carbon dioxide emissions come from energy. We need to start acting now. It's not going to be easy. But the alternatives are worse," Richard Jones, IEA's deputy executive director, said during a presentation on the organization's 2009 World Energy Outlook at the Center for Strategic and International Studies.

In addition to its usual forecast which assumes no significant changes in national policies, the Paris-based organization of industrialized energy-consuming countries' 2009 World Energy Outlook includes a scenario which projects impacts of taking steps which would stabilize greenhouse gas concentrations at about 450 ppm carbon dioxide equivalent by 2030.

This "450 Scenario" would avoid the most severe weather and rising sea level consequences by limiting the overall temperature increase to 2° C., it indicates. "Without a change in policy, the world is on a path for a rise in global temperature of up to 6° C., with catastrophic consequences for our climate," it maintains.

The US Energy Information Administration has included $CO_2$ emissions forecasts for petroleum, natural gas, and coal in its monthly short-term energy outlook since August. IEA has gone further by advocating that steps be taken to curb GHG releases into the atmosphere.

### 'Take the lead'

At a meeting of the group's ministers in October, "a large majority showed their intention to take the lead, organize themselves, and commit to the challenge to reach the 450 Scenario—the energy path of Green Growth," IEA Executive Director Nobuo Tanaka said. "Only by mitigation action in all sectors and regions can we turn the 450 Scenario into reality."

The organization has launched three specific initiatives already, according to Jones. It has started a sustained capacity measurement training project with nonmember countries to get more accurate data from more sources. It is forming partnerships with China, India, Russia, and other non-IEA nations. And it is discussing technology to help countries overcome barriers to understanding what they need and how to get it.

"It's not going to be easy. But the alternatives would be worse," said Jones. "We need to start acting now. Whether or not [the United Nations climate conference in] Copenhagen succeeds, countries will need to start acting on

their own. We also have to continue economic growth to provide jobs for people already on this planet by 2030. That means providing more energy."

Actions are necessary despite a likely decline in global energy use in 2009 as a result of the financial and economic crisis, IEA Chief Economist Fatih Birol said. This has led to a plunge in energy investment because of a tougher financing environment, weaker demand, and reduced cash flows, he indicated. For oil and gas companies, this has meant delayed and canceled projects as well as capital spending cuts.

"Global upstream spending is expected to fall by more than $90 billion, or 19%, the first fall in a decade," he told his audience at CSIS. "If this trend continues and merges with a strong rebound in demand as the world's economies recover, it poses price implications."

### Forecast outlays

Under the WEO's reference scenario, where major climate change policies aren't adopted, $26 trillion in 2008 dollars would be required to meet projected energy demand from 2010 through 2030, equal to $1.1 trillion/year (or 1.4% of global gross domestic product). More than half of that would be needed in countries outside the Organization for Economic Cooperation and Development, where demand and production are expected to increase fastest.

"With little prospect of a quick return to the days of cheap and easy credit, financing energy investment will, in most cases, be more difficult and costly than it was before the [financial and economic] crisis," the report says.

Under the 450 Scenario, another $10.5 trillion would be needed. "But investments in industry, transport, and buildings are more than offset by fuel cost savings, which in the transport sector alone amount to over $6.2 trillion [during] the period," the report continues. The scenario also offers environmental and security benefits, with oil and gas import bills for OECD countries in 2030 much lower than in 2008,

## USCAP: US economic growth would not be reduced by aggressive climate-change actions

**Nick Snow**
*Washington Editor*

US economic growth would not be significantly reduced through 2030 if the nation took aggressive action to address climate change, the US Climate Action Partnership said on Dec. 2.

The group of businesses and environmental organizations said that its economic analysis estimates US gross domestic product would grow 70-71% with the adoption of climate legislation similar to its Blueprint for Legislation during that period, and 71-72% in the absence of climate policy. Royal Dutch Shell PLC, BP PLC, and ConocoPhillips are members.

USCAP's analysis used two economic models similar to ones used by the US Environmental Protection Agency and the Energy Information Administration when they reviewed House legislation passed in June.

"All of the studies, including USCAP's analysis, show employment growing under all scenarios," Janet Peace, vice-president of markets and business strategy at the Pew Center on Global Climate Change, told reporters in a teleconference. "The climate policy is absolutely compatible with robust economic growth."

### Almost imperceptible

The models showed that enacting climate legislation would cause an almost imperceptible dip in domestic GDP growth through 2030, Peace said. Under a business-as-usual scenario without climate legislation, total US economic output was projected to reach $22.3 trillion by 2030. With the USCAP's Blueprint recommendations, the domestic economy would arrive at the same point 2-4 months later, she indicated.

"Early development of offsets is essential," said Peace. "They're necessary for cost containment, such as emissions reductions in agriculture and forestry. Limits or delays in development of either domestic or international efforts will increase the program's costs."

The study also found that complementary actions to develop energy efficiency, transportation, and carbon capture and storage programs will be essential in advancing technology and lowering future energy spending.

"There is no question that we can address the climate challenge in a way that protects consumers while growing our economy," Peace said. "While there are costs involved, they are modest and prudent investments in a cleaner, more effective future."

### 'Best solution'

"We're very comfortable with the idea that markets will deliver the best solution," said Jeff Hopkins, principal advisor on energy and climate strategy at Rio Tinto, a multinational mining company that belongs to USCAP.

He said Rio Tinto and BP are investors in a California power plant that will use a variety of fuels and employ CCS to enhance production at a nearby oil field. "Only a climate policy such as the one USCAP proposes will encourage the integration of various technologies," Hopkins said.

Melissa Lavinson, senior director of federal affairs at Pacific Gas & Electric Co., said, "An industry like ours needs to know what policies are going forward because it makes long-term investment decisions. Utilities expect to spend $1.5-2 trillion, and jobs will be associated with those investments. New technologies will require new workers with new training. Understanding what the rules of the road will be especially critical."

WATCHING GOVERNMENT

Nick Snow, Washington Editor

Blog at www.ogjonline.com

# Biofuels' water impacts

The US government is encouraging the use of biofuels in response to concerns about the country's dependence on imported oil, climate change, and other issues. Water plays a crucial part in all stages of biofuels production, and the Government Accountability Office is studying implications of expanded biofuels production's water use.

The extent to which more biofuels production affects US water resources will depend on the feedstock type selected and how and where it is grown, GAO said in a Nov. 30 report.

It said experts believe that if corn or other conventional feedstocks are used extensively, the impact would be greater than if next generation feedstocks, such as perennial grasses and woody biomass, are used.

"This is because corn is a relatively resource-intensive crop, and in certain parts of the country requires considerable irrigated water as well as fertilizer and pesticide application," GAO said.

The same experts and officials noted that next generation feedstocks' impact on water resources aren't fully known yet because they haven't been grown commercially.

## Efficiency questions

The process of converting feedstocks to biofuels also uses water, the report noted. While biorefineries producing ethanol from corn have grown more efficient, the amount of water needed to convert new feedstocks is not known, it said.

"Finally, experts generally agree that it will be more important to take into account the regional variability of water resources when choosing which feedstocks to grow and where to expand their production," GAO said.

Using certain agricultural practices, alternative water sources, and technologies could mitigate biofuels production impacts on water, GAO said, but it also found barriers to their widespread adoption.

For example, it noted that brackish water or other alternative sources might work for some biofuel conversion phases and reduce refineries' reliance on fresh water.

## 'Remain untested'

Similarly, innovations such as dry cooling systems and thermomechanical processes could reduce water demand, "but many of these innovations are currently not economically feasible or remain untested at the commercial scale," it said.

GAO said many experts identified two main areas where additional research is needed: feedstock cultivation and biofuel conversion, and data on water resources. "For example, some experts noted the need for further research into improved crop varieties, which could help reduce water and fertilizer needs," it said.

It said that several mentioned finding ways to increase algae cultivation commercially and controlling potential water quality problems. Others recommended researching ways to optimize conversion technologies for maximum water efficiency.

"Finally, some experts said that better data on water resources in local aquifers and surface water bodies would aid in decisions about where to cultivate feedstocks and locate biorefineries," GAO said. ✦

and 30% lower in China and India in 2030 than in the reference scenario.

Both scenarios assume that energy prices will rise through 2030. "Consumers will need to recognize that the cheap energy era is over," said Tanaka. "We think that the $147/bbl oil price last year began to change the structure of demand. Two major US automakers went into bankruptcy. The consumer is learning."

In the reference scenario, the average IEA crude oil import price (a proxy for international prices which in 2008 averaged around $3/bbl less than West Texas Intermediate crude, the US benchmark) is assumed in real terms to reach $87/bbl in 2015, $100/bbl by 2020, and $115/bbl by 2030 (in 2008 dollars).

## Lower demand

Under the 450 Scenario, oil prices are assumed to follow the same upward path until 2015 but remain flat from then until 2030 because demand would be weaker. "The oil price is assumed to plateau at $90/bbl in real terms in 2020. Gas prices are correspondingly lower. Coal prices are reduced even more, as demand falls much more than for oil or gas," the report says.

These prices also take into account carbon prices under cap-and-trade systems which are assumed to be introduced in many parts of the world. Under this scenario, the $CO_2$ price within the OECD reaches $50/tonne in 2020 (which increases the cost of a barrel of oil by $21) and $100/tonne in 2030 (which increases oil costs $46/bbl), according to the WEO.

"If there's a financial signal, habits will change. We need a carbon price," Birol said. "The bulk of the discussion now centers on which country reduces $CO_2$ emissions by how much. I think that's wrong. The focus should be on investments and who pays for them." Manufacturers in industrialized nations might want to consider cofinancing reductions in developing countries where they would cost less, he suggested.

Both scenarios forecast long-term

gas demand growth. In the reference case, global demand climbs 41% from 3 trillion cu m in 2007 to 4.3 trillion cu m in 2030, or an average 1.5%/year, driven largely by electric power generation demand. More than 80% of this increase is expected outside the OECD, with the biggest rise in the Middle East.

Gas demand would grow 17% under the 450 Scenario, or an average 0.7%/year, reaching a level in 2030 that would be 17% lower than under the reference scenario.

"The good news is that there's a silent revolution going on in the United States. There's a boom in shale gas which poses implications elsewhere," said Birol. "Many companies and countries thought they could sell LNG to the US, which doesn't need it now. They'll have a lot of gas and will be looking for buyers. We see a glut coming, about 200 billion cu m, by 2015, due to weaker demand." ✦

# GHG health-threat finding sets stage for regulations

**Nick Snow**
*Washington Editor*

Greenhouse gases threaten the public's health and should be regulated, the US Environmental Protection Agency said on Dec. 7. GHG emissions from on-road vehicles contribute to that threat, it added.

"Today's finding is based on decades of research by hundreds of researchers," EPA Administrator Lisa P. Jackson said. "The vast body of evidence not only remains unassailable; it's grown strong, and it points to one conclusion: Greenhouse gases from human activity are increasing at unprecedented rates and are adversely affecting our environment and threatening our health."

The finding follows a study that EPA undertook after the US Supreme Court ruled in 2007 that GHGs fit within the federal Clean Air Act's definition of pollutants. It covers emissions of six gases (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride, according to Jackson.

It does not impose new requirements itself but allows the agency to finalize GHG standards proposed earlier this year as part of a joint rulemaking with the US Department of Transportation, Jackson continued. On-road vehicles contribute more than 23% of total US GHG emissions, and EPA's proposed standards for light-duty vehicles, an on-road vehicle subset, would reduce GHG emissions by nearly 950 million tonnes and conserve 1.8 billion bbl of oil over the lifetime of model year 2012-16 vehicles, Jackson said.

She noted that both she and US President Barack Obama support reaching a legislative solution to global climate change, but added that it's critical for EPA to respond to the Supreme Court's ruling and begin to regulate GHG emissions because they threaten public health. The agency issued proposed findings in April and received more than 360,000 comments during the 60-day comment period that followed, she said.

## 'Politically motivated'

Oil and gas industry groups immediately criticized EPA's action. "There was no compelling deadline that forced EPA's hand on this decision," said American Petroleum Institute Pres. Jack N. Gerard. "It is a decision that is clearly politically motivated to coincide with the start of the Copenhagen climate summit. EPA's finding is inadequate, unsupported by the record, and fails to demonstrate a significant risk of harm to public health or welfare."

National Petrochemical & Refiners Association Pres. Charles T. Drevna, meanwhile, commented, "Individual American consumers and businesses alike will be dramatically affected by this decision that, frankly, is based on selective science, a weak legal and policy foundation, and a failure to account for numerous uncertainties and assumptions in the models it relies on."

Drevna added, "This is yet another example of federal policymakers failing to consider the long-term consequences of a regulatory action for consumers and the economy as a whole."

Congressional Democratic leaders said EPA's finding makes it that much more urgent for Congress to pass climate-change legislation. "Those who fear EPA regulation of global warming pollution will find the answer in the American Clean Energy and Security Act passed by the House this year," said US House Speaker Nancy Pelosi (Calif.).

"Now that the US government has officially ended its era of climate denial, the real endangerment to our planet comes from those who continue to deny the science and delay taking any action," said Rep. Edward J. Markey (Mass.), who cosponsored with Energy and Commerce Committee Chairman Henry J. Waxman (Calif.) the bill which the House passed by seven votes on June 26.

## Key milestone

US Environment and Public Works Committee Chairwoman Barbara Boxer (Calif.), who cosponsored the Senate's current primary climate-change bill with John F. Kerry (Mass.)—which the committee approved despite a boycott by Republican members—said the endangerment finding was a key milestone in EPA's efforts to address global warming under CAA. "It is now clear that if we take our responsibility seriously to protect and defend our people from this threat, the Senate has a duty to act on climate-change legislation that includes major components of the work done by the Energy and Environment committees," Boxer said.

Republicans were more critical.

House Minority Leader John A Boehner (Ohio) said, "Today's EPA announcement paves the way for Washington Democrats' cap-and-trade national energy tax, a bureaucratic nightmare that would make households, small businesses, and family farms pay higher prices for electricity, gasoline, food, and virtually every product made in America."

Joe Barton (Tex.), the House Energy and Commerce Committee's ranking minority member, said, "When scientists whose work is the bedrock for our global warming policy use words like 'travesty' and 'trick' to describe their actions, and banter about how they'll blackball professional journals and delete evidence, it's time to slow down and consider what we're doing, not sound the charge. Regrettably, good sense got run over today when EPA hit the gas instead of tapping the brakes."

James M. Inhofe (Okla.), the Senate Environment and Public Works Committee's ranking minority member, said, "Today, the Obama administration announced an unprecedented rule, one that will have far-reaching implications for each and every America. The administration's endangerment finding will lead to a wave of new regulations and bureaucracy that will wreak havoc on the American economy, destroy millions of jobs, and force consumers to pay more for electricity and gasoline."

Environmental organizations regarded the action more favorably. "As the major global warming summit begins this week in Copenhagen, this announcement couldn't come at a more important time," said Sierra Club Executive Director Carl Pope. "The Obama administration has followed through on its pledge to act and is demonstrating that the US has turned away from eight years of inaction under the Bush administration." ✦

# API, IPAA: White House overlooking oil industry's job-creation potential

**Nick Snow**
*Washington Editor*

The American Petroleum Institute's two top officials expressed concern over the White House's apparent omission from its Dec. 3 jobs forum of chief executives from the oil and gas industry. The Independent Petroleum Association of America's chairman separately said the Obama administration may not recognize the industry's economic contributions.

"Several from our individual companies wanted to come. None of them were invited. Neither were any people associated with oil and gas trade associations, to our knowledge," API Chairman J. Larry Nichols told reporters during a teleconference.

"I think it's a missed opportunity to talk to one of the largest employers and wealth creators in the United States," added API Pres. Jack N. Gerard. "We stand ready as an industry to step forward and aid what we're going to need in the future, which is more energy."

In a separate letter to US President Barack Obama, IPAA Chairman Bruce H. Vincent said the safe and responsible development of domestic energy resources has never failed to create value, not only for those who are directly involved but also for consumers.

"In a modern context, that value can be realized in the form of new, high-wage jobs for the American people; billions of dollars in revenue [for] state, local, and federal governments; and a genuine means of reducing our dependence on foreign, unstable energy suppliers abroad," Vincent said.

## Forum's purpose

The forum will be an opportunity for Obama and his economic team to hear from chief executives, small business owners, and financial experts about ideas for continuing to make the economy grow and putting Americans back to work, White House Press Sec. Robert Gibbs said Nov. 30.

Confirmed guests reportedly included chief executives from Google Inc., AT&T Inc., Comcast Corp., Dow Chemical Co., FedEx Corp., and Quest Diagnostics Inc. The White House did not respond to OGJ's telephone inquiry as to whether oil and gas executives were attending or had been invited.

"We're doing our best in talking to both members of Congress and the administration about the impact this industry can have," said Nichols, who also is chairman and chief executive of Oklahoma City-based independent Devon Energy Corp.

"With more than 15 million Americans unemployed, obviously creating jobs is at the top of the president's list of things to work on, and our industry can help," Nichols said. "The key, of course, is to produce more of the oil and gas we use here at home and stop importing as much," he added.

Gerard noted that the oil and gas industry already supports 9.2 million US jobs and adds more than $1 trillion/year to the national economy, not just through direct employment but also with purchases of goods and services from equipment suppliers, construction companies, management specialists, food service firms, and other businesses. Some US oil and gas industry sectors' wages are twice the national average, he said.

## 'Powerful, dynamic'

The industry continues to be one of the most powerful and dynamic US job-creation forces, said Vincent, who also is president of Houston independent Swift Energy Co. "That spirit of growth and innovation is especially present among our nation's small and independent producers, men and

women who, on average, employ just 12 workers each but still find a way to develop 9 out of every 10 wells in service across the country today," he said.

"We take this work seriously. And we stand ready and willing to put that work to use, in service of the goals and objectives identified by your jobs panel this afternoon," Vincent said in his letter to Obama.

Vincent said he was pleased when the president released a position statement during his recent China trip hailing the US as a leader in shale gas technology and developing the resource in ways which mitigate environmental risks.

"May we add 'creating new jobs' to that list as well?" Vincent said, adding, "Only a couple of years back, analysts predicted that shale gas production in Texas's Barnett shale would create $6.5 billion in economic output and 70,000 jobs. Nice try. In 2008, the Barnett generated more than 111,000 permanent jobs and $11 billion in economic activity—and the expectation is for those numbers to climb dramatically in the years to come."

He and Nichols each cited a recent Penn State University report on the Marcellus shale that found that 29,000 jobs were created along the formation in three US Mid-Atlantic states last year, and that more than 50,000 jobs are expected to be created there by year-end. The study also found that Marcellus development has been responsible for more than $2.3 billion of economic development in the area, Vincent said.

### Revenue down 90%

Vincent joined the two API officials in expressing concern about the Obama administration's and US Interior Secretary Ken Salazar's decisions that have significantly reduced federal oil and gas leasing. "Two years ago, more than $10 billion came into the national treasury from that source," Gerard indicated. "During the first year of this administration, it's been less than $1 billion. We believe we could help bring the amount back."

"The first thing this administration needs to do is stop doing things [that] have a chilling impact on job creation," said Nichols. "The cap-and-trade bill would impose a huge new tax on industries. The president's budget would impose new taxes on our own industry," he said, adding that opening more federal acreage to leasing would be a good second step.

Gerard said, "The American people have spoken on this very clearly and said they would like more access to domestic resources. What has happened since then is a de facto moratorium. Access during the Obama administration's first year has been low, yet the public comment period [for the latest proposed 5-year OCS plan] produced more than 300,000 responses calling for more access."

Gerard continued, "We need no subsidy or stimulus, just access, and Salazar could help us. We're not looking for special treatment. We just want the opportunity to do what we do so well." ✦

# BP CEO: Growing economies demand more energy

*Curtis Williams*
*OGJ Correspondent*

BP PLC Chief Executive Officer Tony Hayward says more money needs to be spent on exploration and development if the world is to meet increasing demand for energy.

Speaking at a news conference in Trinidad, Hayward said BP was projecting that by 2030 the world will need at least 45% more energy than it consumes now.

Hayward said this increase demand will be driven mainly by the world's emerging economies.

"Hundreds of millions of people, driven mainly by India's and China's development, are making the journey from a rural to an urban way of life, and that journey brings with it an explosion in demand for energy," Hayward said.

To meet this increase in demand, BP projects it will require an investment of $25-30 trillion, or and average of "more than $1 trillion/year for the next 20 years."

Hayward said is not happening at the moment because the world economic crisis has led to a reduction in companies' ability to invest in exploration.

Hayward said to face the challenges of energy security and climate change there will also be a need for a more diverse energy mix.

"What has become very clear is that there are no magic bullets, nor is there going to be a 'one-size fits all' solution: each country will have

*"Hundreds of millions of people, driven mainly by India's and China's development, are making the journey from a rural to an urban way of life, and that journey brings with it an explosion in demand for energy."*
***—BP PLC Chief Executive Officer Tony Hayward***

to define its own pathway, based on its natural competitive advantage," he said.

### Focus on gas

Hayward said natural gas is becoming increasingly important in dealing with the energy and environmental challenges facing the world and as the developing economies continue to expand, demand for power is set to grow exponentially.

"We believe the best way of meeting this demand growth, while lowering carbon emissions, is through a switch from coal to gas."

Renewable energy will eventually be important but it will take several decades to become a significant part of the power generation mix. Very long lead times apply to nuclear power as well.

"In the short term, the main choice for expanding generation capacity is between coal and gas. And until clean coal technology has been developed for use at scale—which is still some ways off—gas should be the clear choice," he said.

Hayward added, "[Gas] generates half the carbon emissions of coal. It is abundantly available—even more so than we thought just a few years ago thanks to the unlocking of significant reserves of unconventional gas in North America. And as LNG it is traded in increasingly open markets around the world."

A fundamental part of the world's energy future, Hayward argued, must be gas. After all, he said, it is the fuel that offers the greatest potential to provide the largest carbon reductions—at the lowest cost—and all that by using technology that's available today.

Hayward admitted though that clean coal technology will have to be improved and coal will return as part of the sustainable energy mix. ✦

# IHS CERA says upstream cost decline flattening

Upstream cost declines evident in the first half of the year appear to be flattening, reports IHS Cambridge Energy Research Associates.

In the third quarter, the firm's capital-cost index fell slower than it did earlier in the year, while its operating cost index rose slightly from its first-quarter level.

The indexes assess changes since 2000, costs of which are assigned the value 100.

The third-quarter capital-cost index showed a 6-month decline of 4% to 202. IHS CERA said the decline resulted from lower levels of upstream oil and gas activity, which pulled down costs of drilling rigs and yards and fabrication.

Steel costs for upstream equipment fell by 12% between the first and third quarters of the year, following a 25.2% drop in the previous 6 months. The firm said steel costs appear to have stabilized.

Land-rig costs fell 7% because of reduced activity in the US and Middle East. Costs for offshore rigs fell 3.1% because of weak demand for jack ups.

Cost of yards and fabrication, already hurt by a slump in shipping construction, fell 13% over the past half-year as new orders declined and equipment operators faced higher funding costs.

IHS CERA's upstream operating costs index rose 1% between the first and third quarters of 2009 to 168. The firm attributed the increase to operating personnel costs and increases in the market for consumable materials.

It said a 6% increase in operating personnel costs resulted largely from foreign exchange fluctuations.

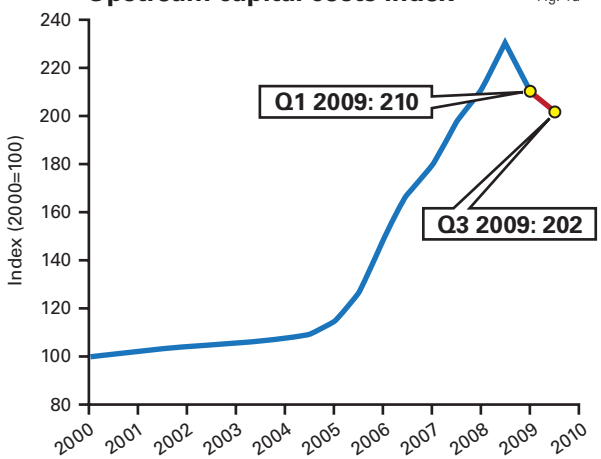
The consumables-cost rise reflected a rebound in feedstock prices and recovery in global demand for chemicals. The largest factor was fuel costs, which increased 9%. ✦

## A LOOK AT UPSTREAM COST TRENDS

Fig. 1

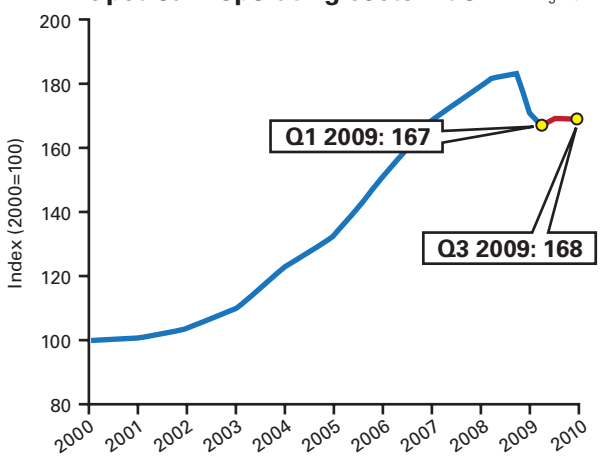
**Upstream capital costs index**

Fig. 1a




**Upstream operating costs index**

Fig. 1b




Source: IHS Cambridge Energy Research Associates

# Study says oil speculation not 'excessive'

As the US Congress and Commodity Futures Trading Commission consider tighter regulation of derivatives trading, a new study suggests excessive speculation wasn't to blame for a record-breaking surge in oil prices in first-half 2008 (OGJ Online, Nov. 24, 2009).

The study by Hilary Till, research associate of the EDHEC-Risk Institute in Nice, France, uses newly detailed data from the CFTC and a traditional standard for assessing speculative activity in relation to hedging in agricultural derivatives markets.

"We can say that, based on traditional speculative metrics, the balance of outright speculators in the US oil futures and options markets was not excessive relative to hedging activity in those same markets from June 13, 2006, to Oct. 20, 2009," concludes Till, a principal and cofounder of Premia Capital Management LLC based in Chicago.

She says her study became possible when the CFTC in October launched the Disaggregated Commitments of Traders report, which provided more detailed categorization of large traders than previously was available. The move relieved some of the ambiguity in the older reporting regime, which treated swaps dealers hedging their positions in futures markets as nonspeculative traders.

Because those dealers "are not hedging in the traditional sense of the word," Till says, "it became difficult, strictly speaking, to understand the balance between (physical) commercial hedging in the futures markets and participation by those not involved in the handling of the physical commodity."

## Study method

Till applied a method for assessing speculation in agricultural futures markets developed by researchers at the University of Illinois at Urbana-Champaign. The researchers based their method on the "speculative T index" devised by economist Holbrook Working in 1960.

In Working's view, commodity futures markets exist to provide the opportunity for hedging and risk management, with speculators importantly balancing positions of hedgers who are buying with those selling. Historically, Till says, speculation was insufficient to provide for commercial hedging needs in agricultural markets.

"The question now, especially in the oil markets, is whether the scales have not been tipped the other way," she says. "If there is more speculation than is required for commercial hedging needs, a futures market becomes one of speculators trading with other speculators."

According to the study, New York Mercantile Exchange futures markets for heating oil and gasoline are within a T-index range not considered excessively speculative for agricultural markets. The conclusion is the same for the Intercontinental Exchange West Texas Intermediate crude oil market for the brief period during which data are available.

For NYMEX crude oil markets, speculation isn't excessive by agricultural standards when options and futures trading are combined, although indicated speculation increased from the summer of 2007 to the summer of 2008.

However, when options positions are excluded, futures-only oil trading on NYMEX is potentially excessive, Till says. And speculation indicators for agricultural markets might not be directly applicable to oil markets, she notes. ✦

# Record Barnett HC content seen in combo play

*Alan Petzet*
*Chief Editor-Exploration*

Hydrocarbon content in the thickest part of the Mississippian Barnett shale combo play in North Texas is so great that even 2-3% recovery is highly economic, said EOG Resources Inc., Houston.

Barnett thickness reaches 1,500-1,700 ft thick in the eastern part of the combo play's 90,000-acre core area in eastern Montague and western Cooke counties on the north side of the Fort Worth basin. There, EOG estimates the formation contains 70 million bbl of oil and 175 bcf of gas in place/sq mile, Loren M. Leiker, senior executive vice-president, exploration, said in late November.

"Hydrocarbons in place [are] more than anywhere else really in the world that we've seen so far" because the formation is so thick and the hydrocarbon charge so rich, Leiker said in describing EOG as the only material participant in the combo play.

EOG plans to run 12 rigs and drill 225 combination play wells in 2010. It has proven more than 50 million boe recoverable to date and had booked 8.4 million boe of reserves by the end of 2008.

EOG's position in the Barnett gas play is "going fine," Leiker said, with 650 drillable locations in Johnson and Hill counties of the company's 1,000 remaining gas sites.

While growing its gas revenue base modestly, EOG is emphasizing liq-

uids the next few years to improve its flexibility to capitalize on whichever hydrocarbon type is more economically desirable.

EOG has drilled 100 wells in 3 years in the combo play, with initial potential rates at 300-1,000 b/d of oil, 130 b/d of natural gas liquids, and 1-2 MMcfd of gas, but it has had to climb a learning ladder, Leiker said.

The early mistake was trying to apply horizontal drilling and fracturing technology learned in the Barnett gas areas to basically the same rock type in the oilier combo play.

Leiker wouldn't detail EOG's technology progress, but he said the company has convinced itself—with no more than 1.5 years on production in its oldest combo area—of its ability to sustain the play's long term profitability and will soon have enough production history to release publicly.

EOG holds 210,000 net acres in Montague and Cooke counties and 144,000 acres in Clay and Archer counties. Of that, 175,000 acres are underlain by a competent Viola bottom seal.

Leiker said the Barnett is so thick in the eastern 10-15% of the core area that EOG can get horizontal-caliber production and reserves from cheaper vertical wells.

The company is pursuing both horizontal and vertical development depending on the formation's thickness in each sector.

An eastern core area vertical well will recover 220,000 boe at $2.2 million or a 70% rate of return, and horizontals will tap 280,000 boe at $3.3 million or 60%.

EOG's estimates of ultimate recovery are increasing with experience.

In November 2009 compared with March 2008, the company estimated it will recover 78,000 bbl of oil/well, up from 75,000; 94,000 bbl of NGL, up from 34,000; and 674 MMcf of gas, up from 260 MMcf.

The amounts are net after royalty. ✦

## WATCHING THE WORLD

Eric Watkins, Oil Diplomacy Editor

Blog at www.ogjonline.com

# Low wattage at PDVSA?

Here's a first for the oil and gas industry: Venezuela's state-owned Petroleos de Venezuela SA (PDVSA) plans to launch the country's first plant to produce energy-saving light bulbs.

The $280-million plant will produce 15 million bulbs the first year and as many as 74 million units/year during its first 5 years of operations.

The plant will be built in the Paraguana free-trade zone by a joint company of PDVSA subsidiary PDVSA Industrial and Vietnam's Dien Quang Lamp JSC, which will provide the technology and raw materials.

The announcement coincided with reports that Venezuela has just 140 oil rigs in operation, down 36% from the 222 rigs operating 2 years ago—a drop in activity that raises question marks.

Is there a serious problem? Will Venezuela's President Hugo Chavez or Oil Minister Rafael Ramirez or PDVSA officials soon be selling apples on street corners?

### Uncredited drilling

Apparently not, if you believe PDVSA's head of exploration Eulogio Del Pino, who said that more oil drilling is taking place in Venezuela than the country is being given credit for.

"The news media that's controlled by the opposition says there are only 56 drills in Venezuela. Those figures are false," said Del Pino, who said there are 140 rigs at work: 50 owned by PDVSA and 90 owned by contractors.

Del Pino offered no explanation for the reduced drilling activity, nor did he say anything about the possibility that production also may have been affected by Chavez's nationalization of dozens of service companies in the Lake Maracaibo oil region.

Significantly enough, Del Pino uttered his remarks at a meeting with other PDVSA officials in the eastern Orinoco region, saying that future production there will reach 3 million b/d over the next 10 years, assuming that all goes well.

### Signs of decay

But all is not going well as a restart of Venezuela's 165,000-b/d Petrocedeno heavy oil upgrader failed to take place over in early December.

The facility, which upgrades heavy oil from the country's Orinoco belt, remains shut for unscheduled maintenance, while the 135,000-b/d Petroanzoategui upgrader remains shut due to boiler problems.

According to analyst IHS Global Insight, Venezuela has just four heavy oil upgraders, so the unplanned closure of two represents "a notable blow" to the country's heavy oil upgrading capability. "It is not clear what problems are afflicting the Petrocedeno facility that would prevent planned start-up," said the analyst, adding that "the lack of any timeframe for operations resumption for not just this upgrader but the Petroanzoategui facility also, is a worry."

A downed refinery or two may say little about a country or its production of oil, but those light bulbs continue to weigh heavily on this editor's mind. One can't help but think that the failure of two upgraders carries a deeper message that can't be ignored.

Sooner or later, however, you can be sure the lights will come on. ✦

# Only two oil sands projects meet new ERCB tailings rules

**Guntis Moritis**
*Production Editor*

Only two tailings management plans for oil sands mining operations comply with the new Alberta Energy Resources Conservation Board (ERCB) Directive 074, according to a Pembina Institute & Water Matters Society of Alberta review.

The oil sands extraction process creates tailings, which are a fluid mixture of water, sand, silt clay, unrecovered hydrocarbons, and dissolved chemicals. The review noted tailings are toxic and cannot be released into the environment. The sand and other coarse solids in tailings settle, but fine solids remain suspended in the water and require long-term containment.

The review said the number of liquid tailings lakes continues to increase in Alberta and in 2009 covered an area of about 130 sq km.

In February, ERCB announced new rules for regulating tailings reclamation. "The new regulations were announced in part because oil sands operators were not meeting targets set out in their original applications," the review said.

Oil sands mining companies submitted tailings management plans to the ERCB on Sept. 30 in accordance with Directive 074: Tailings Performance Criteria and Requirements for Oil Sands Mining Schemes. The directive requires operators to reduce toxic tailings by capturing or extracting the fine particles from the wastewater and then storing the captured solids in disposal areas. The submitted management plans outline how companies would start to reduce the tailings waste.

The review noted the directive requires companies to:

- Capture a minimum portion of fine particles from the tailings. The capture rate (defined as a percentage of total fine particles in the raw oil sands material) increases during 3 milestone years: 20% by June 30, 2011; 30% by June 30, 2012; and 50% by June 30, 2013.
- Create disposal areas for storing the captured particles.
- Ensure the disposal areas meet ERCB's minimum load-bearing strength.
- Prepare annual plans and reports on tailings.

The review found only two of nine projects would meet regulatory requirements starting in 2011. It noted some proposed plans would not meet reductions until 2023 and would not meet rules for developing solid surfaces for more than 40 years.

The plans for the Suncor Energy Inc. Millennium and North Steepbank mine and the Fort Hills Energy Ltd. mine met the ERCB rules, according to the review. Because Petro-Canada, the operator of Fort Hills, merged with Suncor, Suncor submitted the plan for Fort Hills.

The review said plans not meeting the new rules included the Canadian Natural Resources Ltd.'s Horizon; Imperial Oil Ltd.'s Kearl: Shell Canada Ltd.'s Muskeg River and Jackpine; and Syncrude Canada Ltd.'s Mildred Lake, Aurora North, and Aurora South projects.

A copy of the Pembina and Water Matters review is available at www.oilsandswatch.org/pub/1934. ✦

# Floating production system orders resume

**Guntis Moritis**
*Production Editor*

Orders for floating production systems have resumed after a 1-year hiatus, according to the latest International Maritime Associates Inc. assessment.

IMA reported that since mid-2009, companies have placed orders for one tension-leg platform and six floating production, storage, and offloading vessels. This includes an FPSO and TLP combination for Papa Terra off Brazil, an FPSO for Parque das Baleias off Brazil, an FPSO off West Africa, two FPSOs off Vietnam, and an FPSO in the Adriatic.

IMA noted companies have 170 new projects in the bidding, design, or planning stages that potentially may require a floating production or storage system.

Brazil has the most new potential projects with 34, followed by 31 off West Africa, 26 off Southeast Asia, 25 in the Gulf of Mexico, and 19 off Northern Europe, according to IMA.

It said 43 of the 170 planned projects are in the bidding or final design stage and likely to start within the next 12-24 months. It said Petroleo Brasileiro SA has the most potential projects with 28, and 10 operators account for 53% of the potential projects.

The number of production floaters looking for work increased during the past year, and there could be as many as 23 units now available, IMA said.

It reported off-hire production floaters being remarketed as of November included Munin FPSO, Griffin Venture FPSO, Front Puffin FPSO, Ruby Princess FPSO, Ming Zhu FPSO, Uisge Gorm FPSO, Glas Dowr FPSO, Modec Venture I FPSO, Falcon FPSO, Rang Dong 1 FPSO, BW Carmen FPSO, OPTI-EX semi, and FPF 1 semi.

Speculative units being marketed include Nexus 1 FPSO, Deep Producer 1 FPSO, MT Arc FPSO, Sevan 4 FPSO, and Sevan 5 FPSO.

Off-hire units with questionable status include Jamestown FPSO, San Jacinto FPSO, Orca semi, and Olinda Star semi.

Also a speculative unit partly completed and available is the MPF hull. ✦

GULF MARGINAL PRODUCTION—2

# Model identifies marginal structures, future output

**Mark J. Kaiser**
*Louisiana State University*
*Baton Rouge*

All producing properties are unique and have costs and benefits specific to each stage of its life cycle.

As fields mature and operations transition into the later stages of their production cycle, decreasing revenue streams, higher operating costs, and fewer upside opportunities lead to declining profitability. Eventually, properties are abandoned when marginal cost exceeds the marginal revenue of production.

In Part 2 of this three-part series, we categorize the inventory of committed assets in the shallow water Gulf of Mexico and introduce the model framework used to identify marginal structures and the level of their future production.

## Asset classification

### Committed assets

In January 2007, the Gulf of Mexico had 3,847 structures.

About 40% of the structures were not in production, either because they were held by lease production or preparing for decommissioning. In water less than 1,000 ft deep, 2,364 structures were producing.

A structure is said to be producing if it produces any amount of oil or gas in the year of observation, while an idle structure once produced hydrocarbons but has not been productive for at least 1 year prior to 2006. A few hundred auxiliary structures have never produced and are also included in the total of nonproducers.

Committed assets refer to those structures that were producing in the gulf at the time the study was initiated (January 2007) and do not involve planned or anticipated installations from future development plans or projects installed after the study date.

### Production type

Producing structures are classified by primary output and structure type in Table 1.

A structure is labeled an oil structure if its producing gas-oil ratio is <5,000 cu ft/bbl and a gas structure if its GOR is >5,000 cu ft/bbl. Over two thirds of the committed asset inventory are gas producers.

Fixed platform is the most common structure type, followed by caissons and well protectors. The unknown category in Table 1 represents structures

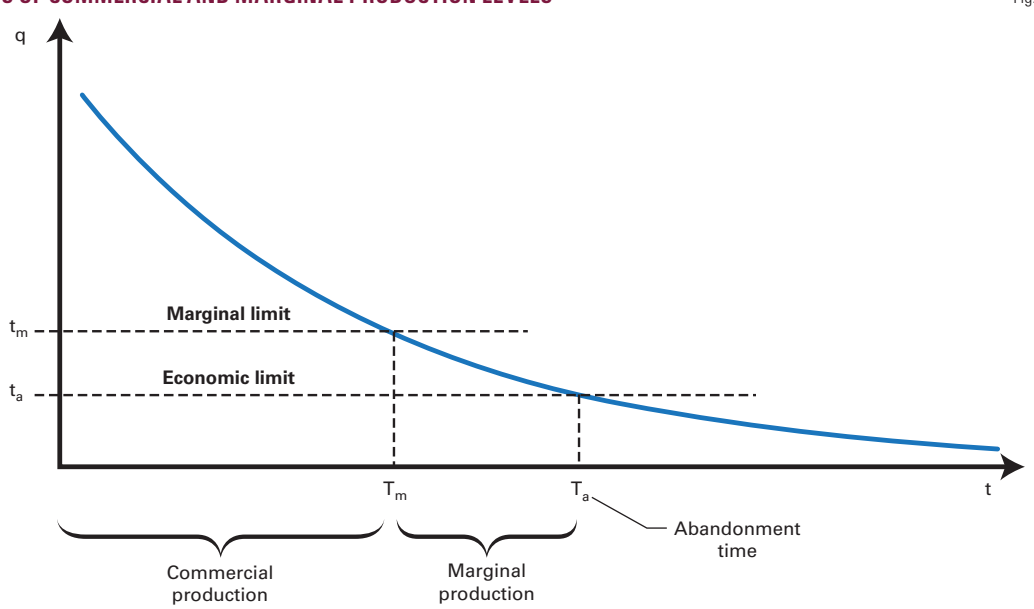
GULF ASSETS CLASSIFIED BY MAIN PRODUCTION, STRUCTURE TYPE, 2006

Table 1

| Production type | Caisson | Fixed platform | Well protector | Unknown | Total |
|---|---|---|---|---|---|
| Gas | 458 | 1,093 | 157 | 27 | 1,735 |
| Oil | 126 | 416 | 72 | 15 | 629 |
| **All** | **584** | **1,509** | **229** | **42** | **2,364** |

LIMITS OF COMMERCIAL AND MARGINAL PRODUCTION LEVELS

Fig. 1




The marginal limit $t_m(s)$ and economic limit $t_a(s)$ are empirically defined parameters used to delineate commercial and marginal production levels.

with missing identifiers on structure type or water depth.

## Production class

To facilitate an automated approach to production forecasting, each producing structure is classified by age and profile type into five subcategories, denoted as: (I) Young, (II) Normal, (III) Chaotic, (IV) Latecomer, and (V) Unknown.

A young structure is defined to be any structure with less than 7 years' production history. For young structures, a production forecast is achieved through a history match, using the statistical characteristics of structures that have been previously removed as the matching set.

Normal and chaotic structures have produced to a condition of pseudosteady-state flow and allow curve fitting with standard regression techniques. Normal structures have production profiles that are best-fit by a decline curve with $R^2 \geq 0.75$, while chaotic structures have a best-fit decline curve with $0.50 \leq R^2 < 0.75$.

Latecomer structures exhibit unusual profiles, usually multiple peaks, that do not conform to standard curve fitting techniques. For latecomer structures, various heuristic techniques are applied to generate the forecast curves.

The number of active structures classified by production class and type is shown in Table 2. Production modeling of the shallow water structures yielded 525 young structures, 1,280 normal structures, 90 chaotic structures, 427 latecomers, and 42 unknown structures.

Most of the structures were modeled with standard decline curves, but a significant number of young structures, as well as structures with latecomer attributes, also exist. Production forecasting associated with young and latecomer structures are expected to be subject to a larger degree of uncertainty than normal assets.

## Economic status

Producing structures are classified as either economic or marginal depending on the level of its revenue relative to a structure-specific threshold at the time of observation (Fig. 1).

If the revenue of structure s at time t is denoted as r(s, t), and the value of the marginal and economic thresholds are denoted as $\tau_m(s)$ and $\tau_a(s)$, $\tau_m(s) > \tau_a(s)$, then a structure is said to be economic at time t if $r(s, t) \geq \tau_m(s)$.

A structure is said to be marginal at time t when the revenue of the structure falls below the marginal threshold but remains above the abandonment threshold; i.e., $\tau_a(s) < r(s, t) < \tau_m(s)$. At $r(s, t) = \tau_a(s)$, the economic limit of the structure has been reached, where the operating cost equals the revenue generated from production, and whereupon a rational decision maker would stop production.

The time a structure turns marginal and uneconomic is denoted as $T_m(s)$ and $T_a(s)$, respectively. Production during the time a structure is classified as economic or marginal is called economic and marginal production.

## Equations

(1) $\Sigma = \{(d, P^o, P^g, m, a, D) \mid 0.05 \leq d \leq 0.30, 80 \leq P^o \leq 160, 8 \leq P^g \leq 16, a \leq m \leq 6, 0.5 \leq a \leq 0.3, 0.8 \leq D \leq 0.14\}$

(2) $q^i(s) = (q^i(s, 1), q^i(s, 2), \cdots)$

(3) $r(s, t) = q^o(s, t) P^o + q^g(s, t) P^g$

(4) $r(s) = (r(s, 1), r(s, 2), \cdots)$

(5) $T_m(s) = \{t \mid r(s, t)) = m \bullet \tau_m(s)\}$

(6) $T_a(s) = \{t \mid r(s, t) = a \bullet \tau_a(s)\}$

(7) $r(s) = (r(s, 1), r(s, 2), \ldots, r(s, T_a(s))$

(8) $q^i(s) = (q(s, 1), \cdots, q(s, T_m - 1), q(s, T_m), \cdots, q(s, T_a)) = (q^i_e(s), q^i_m(s))$

(9) $q^i_e(s) = (q(s, 1), \cdots, q(s, T_m - 1), 0, \ldots, 0)$

(10) $q^i_m(s) = (0, \ldots, 0, q(s, T_m), \ldots, q(s, T_a))$

(11) $r(s) = (r(s, 1), \cdots, r(s, T_m - 1), r(s, T_m - 1), r(s, T_m), \cdots, r(s, T_a) = (r_e(s), r_m(s))$

(12) $r_e(s) = (r(s, 1), \cdots, r(s, T_m - 1), 0, \ldots, 0)$

(13) $r_m(s) = (0, \ldots, 0, r(s, T_m), \ldots, r(s, T_a))$

(14) $Q^i_e(s) = \sum_{t=1}^{T_m - 1} q^i_t(s)$

(15) $Q^i_m(s) = \sum_{t=T_m}^{T_a} q^i_t(s)$

(16) $Q^i_T(s) = Q^i_e(s) + Q^i_m(s)$

(17) $V_e(s) = \sum_{t=1}^{T_m - 1} \frac{r_t(s)}{(1 + D)^t}$

(18) $V_m(s) = \sum_{t=T_m}^{T_a} \frac{r_t(s)}{(1 + D)^t}$

(19) $V_T(s) = V_e(s) + V_m(s)$

(20) $f = \alpha_0 + \sum_{i=1}^{6} \alpha_i X_i$

## Model framework

The number of committed shallow water structures classified as economic or marginal and the quantity and value of their production is forecast as follows:

- *Initialization.* Determine the production class of each structure, select the model input variables, and quantify the manner in which the input parameters are expected to vary.
- *Production forecast.* Forecast future production based on model parameters assuming stable reservoir and investment conditions.
- *Revenue forecast.* Forecast future revenue for assumed hydrocarbon prices and marginal and abandonment thresholds.
- *Structure classification.* Classify a structure as economic and its production as economic when generated revenue falls above the marginal threshold, and a structure as marginal and its production as marginal when its gross revenue falls above its abandonment threshold but below its marginal threshold.
- *Categorization.* Categorize and count the structure count, annual production, and discounted future revenue from the collection of economic and marginal structures.

## Initialization

### Variable selection

The user selects the input set depending upon the objectives of the problem. The variables employed in this analysis include: the price of oil and gas ($P^o$, $P^g$), the marginal and abandonment threshold multipliers (m, a), and the discount rate (D).

An exponential model with decline parameter d is associated with those structures that do not have a sufficient production history to perform regression analysis. The input parameters of the model are denoted by the vector (d, $P^o$, $P^g$, m, a, D).

### Parameter distribution

Each system parameter is governed by a distribution function $f_i$, i = 1, …, 6. The specification of each function is determined by empirical analysis or user preference.

For example, if the historic price of oil is determined to follow a Lognormal distribution according to the parameters μ and $\sigma^2$, $P^o \sim LN(\mu, \sigma^2)$, the user may model future prices according to this specification or may prefer to assume another distribution type, such as the uniform distribution U(a, b) with end points (a, b). Model variables are held fixed for all structures across time for each iteration of the simulation.

### Design space

The distribution functions of the model variables that are employed in the simulation are shown in Table 3. We refer to the collection of input variables and the intervals of their distributions as the design space Σ shown by Equation 1.

The design space serves to represent reasonable bounds on the model parameters to help ensure that we encompass user beliefs in future scenarios. If the distribution type or any parameter interval of the design space changes, output values and the coefficients of the regression model will also change.

Fortunately, small perturbations in Σ along one or more directions do not change the output significantly, because the parameters are already defined through reasonably large intervals and perturbations near the endpoints of the interval in either direction (e.g., changing d ~ U(0.05, 0.30) to d ~ U(0.08, 0.25)) will only make an incremental change in the design volume.

Changes in the dimensionality of the design space, however, which would occur by adding or deleting one or more variables, will have a significant impact since in this case the structural aspects of the model have been modified.

## Methodology

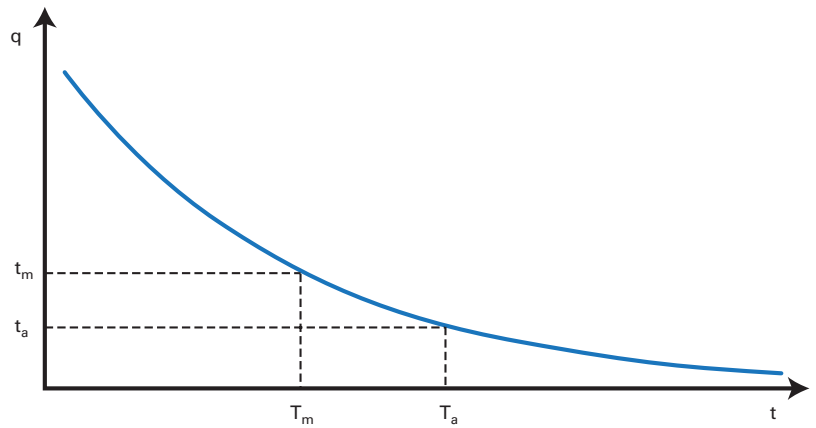
### Production forecast

For each structure, the best-fit production curve is used to forecast future oil and gas production under the assumption that production will not be altered in the future due to reservoir-production problems or additional investment.

Extrapolating the results of an empirically derived equation to the future assumes that all the factors affecting performance in the past have exactly the same cumulative effect in the future. This is a strong assumption, referred to as "stable reservoir and investment conditions," and the ability of our model to accurately reflect future production is highly dependent

MARGINAL AND ABANDONMENT THRESHOLDS

Fig. 2




The marginal and abandonment thresholds $t_m(s)$ and $t_a(s)$ determine the end of economic production and the start of marginal production and when the structure is no longer able to produce commercially and is abandoned.

on this assumption.

The production forecast for each structure for each hydrocarbon stream i (i = oil, gas, boe) is initialized in the year 2006 (t = 1) and given by $q^i(s)$ as shown by Equation 2.

## Revenue forecast

Revenue is estimated by multiplying the oil and gas production forecast by the average market hub prices in the year received.

Hydrocarbon quality (API gravity, sulfur content, etc.) and transportation expense (netback cost) to deliver production to market are not considered. Oil and gas prices are assumed constant throughout the life cycle of the structure. Revenue for structure s in year t is computed by Equation 3 yielding the revenue forecast vector r(s) shown in Equation 4.

## Structure classification

Production transitions from commercial to marginal status at the marginal limit $\tau_m(s)$. At the economic limit, the structure will be abandoned (Fig. 1).

The time at which a structure becomes marginal is determined by comparing the revenue of the structure in year t, r(s, t), to the marginal threshold of the structure,$\tau_m(s)$, as shown by Equation 5.

The time at which a structure is no longer profitable is determined by comparing the revenue r(s, t) to the economic limit of the structure, $\tau_a(s)$, shown by Equation 6.

The values of m and a are selected from user-defined distributions to capture the sensitivity of the model output to variations in threshold levels (Fig. 2). Multiplying the thresholds by factors m and a will shift the levels up or down relative to their baseline position, inducing either an earlier or later transition.

The values of $\tau_a(s)$ are determined using historic data for structures categorized according to structure type, primary production, and water depth. The value of $\tau_m(s)$ is fixed at a multiple of the economic limit, selected as $2\tau_a(s)$. Since a ~ U(0.5, 3) and m ~ U(a, 6), the maximum spread between thresholds will range between 4 to 24. Note that the interval defining the marginal threshold multiplier is bound below by the abandonment multiplier to ensure that for each iteration of the simulation the marginal threshold is always greater than the abandonment threshold.

$T_m(s)$ denotes the time when structure production transitions from economic to marginal status. $T_a(s)$ denotes the time when production is no longer profitable and cash flow terminates. The cash flow vector given by Equation 4 terminates at $T_a(s)$ as shown in Equation 7.

We assume that once a structure reaches its economic limit it will be removed from the gulf. According to federal regulations, structures only need to be removed from a lease once lease production stops. We did not incorporate this aspect of leasing regulations into the model since it does not affect the production forecast.

### GULF ASSETS CLASSIFIED BY PRODUCTION TYPE, CLASS, 2006

Table 2

| Production class | Production type — Gas | Oil | Total |
|---|---|---|---|
| Young | 462 | 63 | 525 |
| Normal | 854 | 426 | 1,280 |
| Chaotic | 64 | 26 | 90 |
| Latecomer | 378 | 49 | 427 |
| Unknown | 27 | 15 | 42 |
| **Total** | **1,735** | **629** | **2,364** |

### MODEL PARAMETERS, DISTRIBUTION FUNCTIONS

Table 3

| Parameter | Notation (unit) | Distribution* |
|---|---|---|
| Decline rate | d (%) | U (5, 30) |
| Oil price | $P^o$ ($/bbl) | N (120, 20) |
| Gas price | $P^g$ ($/Mcf) | N (12, 2) |
| Marginal threshold multiplier | m | U (a, 6) |
| Economic limit multiplier | a | U (0.5, 3) |
| Discount rate | D (%) | U (8, 14) |

*U (a, b) denotes the Uniform distribution with end point (a, b). N (μ, $\sigma^2$) represents the Normal distribution with mean μ and variance $\sigma^2$.

## Categorization

An asset will transition from economic to marginal status at some point during its life cycle, and continue to produce marginally until it becomes unprofitable. The production profile $q^i(s)$ of each structure is decomposed into its economic and marginal components, $q^i_e(s)$ and $q^i_m(s)$, based upon the values of $T_m(s)$ and $T_a(s)$, shown in Equation 8.

"Economic" production is defined by q(s,t) for t = 1, …, $T_m$–1, and "marginal" production is defined for t = $T_m$, …, $T_a$, given by Equations 9 and 10. At any point in time, a structure is either "economic" or "marginal."

The production and revenue levels at which a structure transitions between the economic and marginal states is used to delineate commercial and marginal production. From an operator's perspective, this classification would not be considered a production milestone, but for modeling purposes, it is useful to categorize production and structures in this manner.

The revenue stream is similarly segmented into economic and marginal components corresponding to its economic and marginal production terms given by Equation 11. $r_e(s)$ corresponds to the economic revenue stream and $r_m(s)$ corresponds to the marginal revenue stream, shown in Equations 12 and 13.

## Decomposition

The cumulative production, Q(s), and discounted revenue, V(s), associated with structure s is decomposed into economic and marginal components for oil, gas, and boe output streams, beginning from 2006 (t = 1) through the time the structure reaches marginal status ($t < T_m(s)$), and thereafter, until the structure is no longer economic ($T_m(s) \le t < T_a(s)$). The values of $Q^i_e$, $Q^i_m$, and $Q^i_T(s)$, are given by Equations 14-16. See Fig. 3 for the cumulative production and operational milestones.

The discounted revenue of the economic and marginal production streams are computed utilizing an industry-wide discount rate D. The values of the economic, marginal, and combined valuations—$V_e(s)$, $V_m(s)$, and $V_T(s)$—are given by Equations 17-19.

## Simulation-regression analysis

The input parameters for each loop of the simulation include (d, $P^o$, $P^g$, m, a, D) and the output include $\{\sigma_e(\Gamma)$, $\sigma_m(\Gamma)$, $Q_T^o(\Gamma)$, $Q_T^g(\Gamma)$, $V_e(\Gamma)$, $V_m(\Gamma)$, $V_T(\Gamma)\}$, where $\Gamma$ represents the aggregate of the five production classes described previously (young, normal, chaotic, latecomer, unknown).

The model curves used to forecast production is fixed, with the exception of structures in the latecomer class where a subset of profiles is modeled with an assumed decline parameter. The values of (d, $P^o$, $P^g$, m, a, D) are sampled from their respective distribution functions for each loop of the simulation, the output metrics are computed, and after a sufficient number of computations, the model outputs are regressed against the input parameters.

## Model structure

## Model specification

A linear model is specified in Equation 20 that relates the output measures to the input parameters. The value of the output functions f are selected from the set $\{Q_e^i, Q_m^i, Q_T^i, V_e, V_m, V_T\}$ while the input parameters $(X_1, X_2, X_3, X_4, X_5, X_6)$ = (d, $P^o$, $P^g$, m, a, D).

A linear model is specified for ease in interpretation; if model results turn out to be unacceptable, or if significant interaction effects are expected, it is straightforward to apply a nonlinear specification. The model coefficients $\alpha_i$, i = 0, …, 6 are unique to f and will vary with the size, shape, and dimension of the design space.

## Expected signs

The signs of the model coefficients are expected to follow certain values.

The coefficient $\alpha_0$ represents the fixed term (intercept) of the functional and its sign is indeterminate. The inclusion/exclusion of the fixed term coefficient in the formulation is user dependent.

The coefficient $\alpha_1$ is associated with d, which as discussed previously, defines the rate of decline for a subset of latecomer structures (those structures that did not yield best-fit curves or have enough data to perform a forecast). The magnitude of the coefficient $\alpha_1$ relative to the other model coefficients depends upon the proportion of total production controlled by this subset of assets.

If d increases, and all other model parameters are held fixed, structure production will decline faster and reach its economic limit sooner, and so the quantity of reserves and its value will decline. We would thus expect $\alpha_1 < 0$ for the functionals $Q_e^i$, $Q_m^i$, $Q_T^i$, as well as $V_m$, $V_e$, $V_T$, since increasing d will lead to declining cumulative production and value.

The coefficients $\alpha_2$ and $\alpha_3$ are associated with the price of oil and gas, respectively. As $P^o$ and $P^g$ increase, revenue streams for all assets will increase, delaying the onset of the economic limit. This will allow the production of additional reserves, which at elevated prices, will lead to a greater discounted cash flow. Thus, increases (decreases) in $P^o$ and $P^g$ will lead to increases (decreases) of $\alpha_2$ and $\alpha_3$, and so we would expect $\alpha_2$, $\alpha_3 > 0$ across all the functional outputs $Q_j^i$ and $V_j^i$ (i = oil, gas; j = m, e, T).

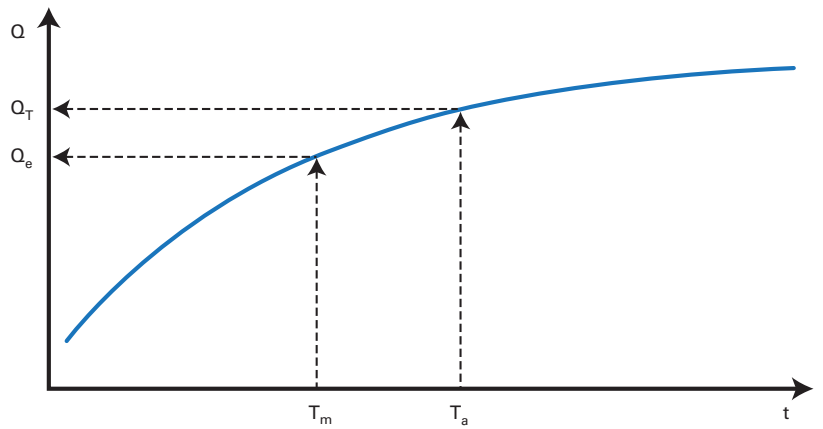
We expect differences to exist in the relative magnitude of oil and gas price for a particular asset (depending, say, if it is primarily an oil or gas producer) and on the stage of its life cycle; e.g., if it is economic or marginal. Because the value of economic production is expected to be at least an order-of-magnitude larger than a marginal producer, oil and gas prices are expected to play a more significant role for economic production.

The coefficient $\alpha_4$ is associated with the multiplier m, and the coefficient $\alpha_5$ is associated with the multiplier a. Recall that m and a are used to vary the marginal and economic thresholds $\tau_m$ and $\tau_a$. The impact of the variation in the multipliers varies depending upon the functional under consideration.

The value of m ranges over a positive interval bounded below by a and above by twice the upper limit of the economic threshold interval. As m increases, $m \cdot \tau_m(s)$ will increase, and production will become marginal at an earlier time, decreasing the amount of economic production ($Q_e$) and its value ($V_e$). Since marginal production occurs at an earlier time and at a higher rate, the amount of production that is classified as marginal ($Q_m$) will subsequently increase along with its value ($V_m$).

The value of the coefficient $\alpha_4$ is

**CUMULATIVE PRODUCTION PROFILE** Fig. 3




The cumulative production profile evaluated at $T_m(s)$ yields the economic production, $Q_e$, and at abandonment $T_a(s)$, the structure has produced all of its reserves, $Q_T$. The quantity of marginal production is computed as $Q_m = Q_T - Q_m$.

thus expected to be negative for the functionals $Q_e$ and $V_e$, and positive for $Q_m$ and $V_m$. For the composite functionals $Q_T$ and $V_T$, coefficient $\alpha_4$ will not enter into the model formulation because there is no need to segment the production and revenue streams.

The variable a ranges over a positive interval, and as a increases, $a \cdot \tau_a(s)$ will increase, forcing production out of profitability at an earlier time. This should not have a measurable impact on $Q_e$ and $V_e$, but the change will reduce marginal production ($Q_m$) and its value ($V_m$). Thus, the coefficient $\alpha_5$ will not enter into the economic production model but is expected to be negative for the functionals $Q_m$ and $V_m$. By linearity, $Q_T$ and $V_T$ should also be negative. Coefficient $\alpha_5$ will not enter into the $Q_e$ and $V_e$ functional since the amount and value of economic production is not influenced by what happens at the end of the life of the structure.

The coefficient $\alpha_6$ is associated with the discount rate D used to compute present value, and thus, will only influence the valuation estimates $V_m$, $V_e$, and $V_T$. The manner in which discount rate varies with present value is well known: as D increases, the value of future revenue declines, and so we expect the sign of coefficient $\alpha_6$ to be negative for all three valuation functionals.

Further, since changes in discount rate have a greater impact on early cash flows, we would expect that the magnitude of $\alpha_6$ would be greater for $V_e$ than $V_m$ since it is defined earlier in the life of cycle of the asset. Coefficient $\alpha_6$ is not included in the model specification for cumulative production since it is only relevant in the valuation estimate.

*Next: The author models the number of committed assets in the Gulf of Mexico that are expected to be marginal over a 60-year horizon.* ✦

## Brazil

Petroleo Brasileiro SA has towed out the platform jacket for Mexilhao gas field for setup in the northern Santos basin off Brazil.

The 182 m tall jacket left a fabrication yard in the Niteroi borough of Rio de Janeiro on the morning of Nov. 19 for the 140-km tow to the field location off Sao Paulo state. Mexilhao is expected to go on production in 2010.

Mexilhao is Brazil's largest fixed gas platform. Production capacity is 530 MMcfd of gas through a pipeline with landfall at Caraguatatuba, where the Monteiro Lobato gas treatment plant is under construction. The plant will also handle gas from Urugua and Tambau fields off Rio de Janeiro and from the Tupi field pilot in the Santos basin.

## New Zealand

Global Resource Holdings LLLP, Littleton, Colo., is seeking farmout partners to explore the 8.1-million-acre PEP 38451 in the deepwater Taranaki basin off New Zealand.

GNS Science and Australian Worldwide Exploration have completed seismic interpretation reports based on 3,400 line-km of proprietary 2D seismic shot in December 2008 and January 2009. The reports confirm that all of the essential elements of the petroleum system are present.

A thick sedimentary section includes a large untested Late Cretaceous delta that contains significant volumes of source rocks, excellent reservoir facies, and good seals.

Global's newly processed seismic data images potential source rocks in the extensive Rakopi Formation coal measures that are confidently tied to well data. The Rakopi formation, the proven source rock for oil in Maui, Maari, and Tui fields, is up to 1 km thick and covers an area of nearly 20,000 sq km in PEP 38451.

## Gulf of Mexico

Helix Energy Solutions Group Inc., Houston, said its Energy Resource Technology GOM subsidiary made a deepwater Gulf of Mexico oil discovery in Green Canyon Block 490 and made a shelf discovery at South Timbalier 145 field.

The Green Canyon discovery on the Jake prospect went to 13,504 ft in 3,740 ft of water and cut 134 ft of net oil and gas pay in a single interval. The well was conventionally wireline logged and fluid samples were recovered. It was cased and temporarily abandoned for a future subsea completion.

Following the discovery, Helix's estimate for the prospect is 50-75 bcfe gross proved, probable, and possible recoverable. Development options are under study, and production is estimated to start in mid-2011. ERT's working interest is 25%.

Another new well that ERT drilled in South Timbalier 145 field, where it is operator with 75% working interest, went to 14,193 true vertical depth and logged 20 ft of oil and gas pay. The well is being completed and expected to go on production in December 2009.

## Alabama

Venture Oil & Gas Inc., Laurel, Miss., gauged an exploratory well off the southeast flank of Huxford (Smackover) field in Escambia County, Ala.

The 1 Mason 36-14, in 36-2n-6e, 22 miles west of Brewton, flowed at the rate of 457 b/d of 43° gravity oil and 538 Mcfd of gas on a $^{10}/_{64}$-in. choke with 2,627 psi flowing tubing pressure from Smackover perforations at 14,902-936 ft. Gas is 1,500 ppm hydrogen sulfide.

## Oklahoma

Red Fork Energy Ltd., Perth, said a well east of Vinita, Okla., logged 52 ft of Devonian Woodford shale above TD of 485 ft with excellent log characteristics and gas shows across the entire section.

The well is the Wattenbarger 1-22, in 22-25n-21e, Craig County, 5 miles east of Vinita. Top of Woodford shale is at 385 ft.

# Upgrade optimizes Weyburn tank vapor recovery, pressure relief

**Kenneth. J. Vargas**
*Falcon EDF Ltd.*
*Calgary*


An upgrade of the Weyburn tank battery vapor-recovery system eliminated the problem of the tank pressure and vacuum relief valves (PVRVs) venting to the atmosphere.

The work involved running a simulation that used the Peng Robinson Sour (PRS) equation of state to match the production tank vented flows. Once the simulation obtained the match, the next step entered the maximum expected future tank vented flows into a process simulation.

The maximum PRS simulated flows provided the basis for sizing the equipment for the upgrade.

## Weyburn battery

EnCana Corp.'s Weyburn Saskatchewan oil battery reinjects dense-phase $CO_2$ for enhancing oil recovery. The battery separates produced gas from the oil and then compresses the gas for recycling it back into the reservoir together with $CO_2$ obtained from the Great Plains Synfuels Plant, in Beulah, ND.

Because the associated and produced gas contains $H_2S$ and $CO_2$, storage of the oil and water requires a closed system that includes:

- Two 10,000-bbl and one 33,000-bbl custom built water tanks.
- Two 10,000-bbl oil tanks.
- One 5,000-bbl slop tank.

Weyburn reinjects the produced water for reservoir pressure maintenance. The oil enters a pipeline to a custody-transfer sales point.

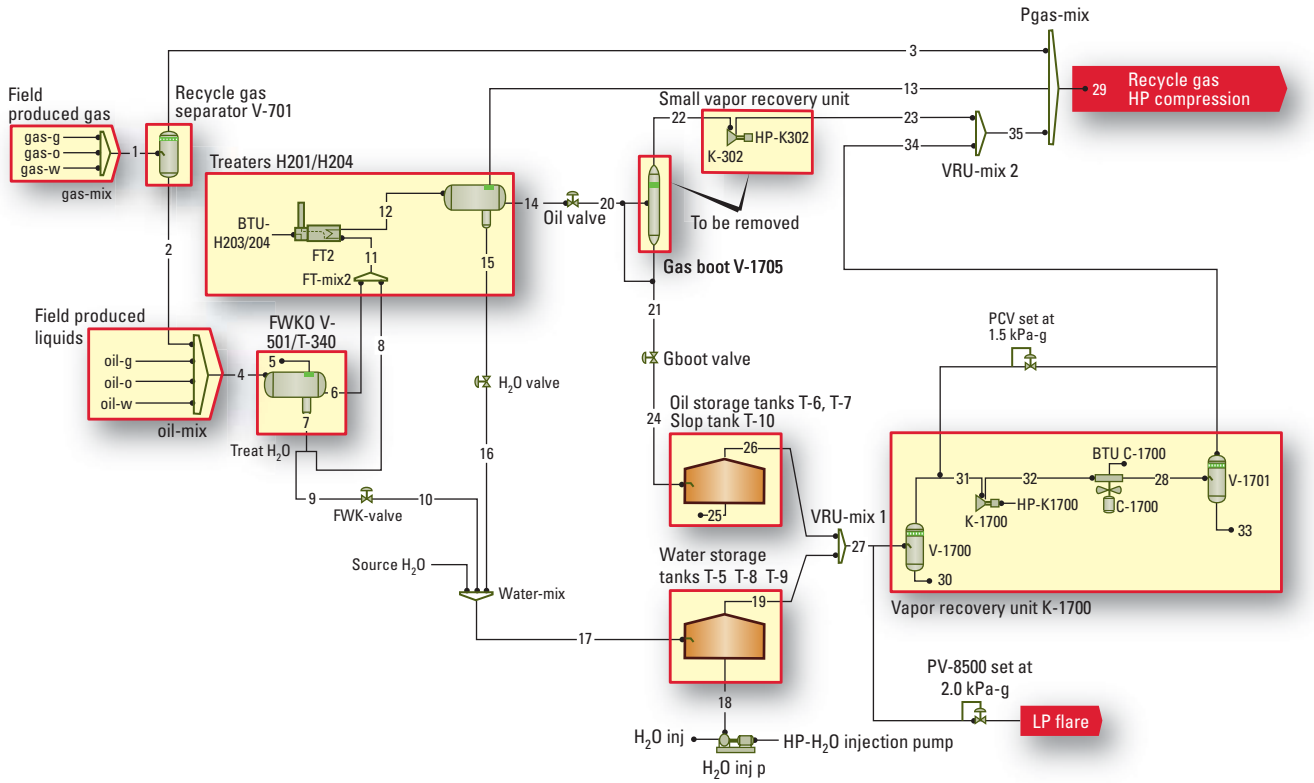
Because $CO_2$-EOR has increased oil and associated water production, associated gas from the oil and water tanks also has increased.

$CO_2$ is very soluble in water; hence water contributes 72% of the tank

*The Weyburn tank battery in Saskatchewan processes injected and produced fluids including $CO_2$ injected for enhancing oil recovery (Fig. 1)*

## WEYBURN BATTERY

Fig. 2




vented gas, while produced oil accounts for the remaining 28%.

### Existing facilities

Before the upgrade, an NPS 10-in. gathering line collected the vapors from all tanks. The vapors went either to the vapor-recovery compressor or above a certain pressure via a pressure control valve (PV-8500) to flare.

If the gathering line's pressure exceeded the relief pressure of the tanks, the PVRV vented the vapor to the atmosphere. The lowest set pressure is at the large water tank with a set PVRV pressure of 3 kPa-g or 7 oz/sq in.

Table 1 summarizes key data for the production and slop tanks and Fig. 1 shows the six tanks.

Fig. 2 shows a simplified diagram of the flow. At the start of this study, EnCana had scheduled some equipment for decommissioning, such as the VRU (K-302) and the gas boot (V-1705).

The existing K-1700 VRU (rated at 1.3-2.5 MMscfd at simulation conditions) could handle the existing flows. When the VRU flow rates reach 2.5 MMscfd, the plan was to install a second twin VRU.

Tables 2 and 3 show the material balance calculations for Streams 4, 17, 20, 23, 28, and 35 indicated in Fig. 2. Table 2 is for flow before the upgrade, and Table 3 is for the flow for the maximum flow rates for designing the vapor-handling equipment.

The battery has three inlet separators: a high-pressure gas separator (V-701) and two free-water knockouts (V-501 and T-340). The two free-water knockouts feed the four treaters (H-201 to 204) and most of the water to the produced water tanks.

The high-pressure gas separator feeds the recycle compression (not shown or included in the PFD material balance).

The diagram represents the oil treaters as a heater (FT2) and a separator (H-204). These units make up one complete treater. The treaters feed the gas boot V-1705 and the produced water tanks T-5, 8, and 9.

The gas boot (V-1705) feeds the oil

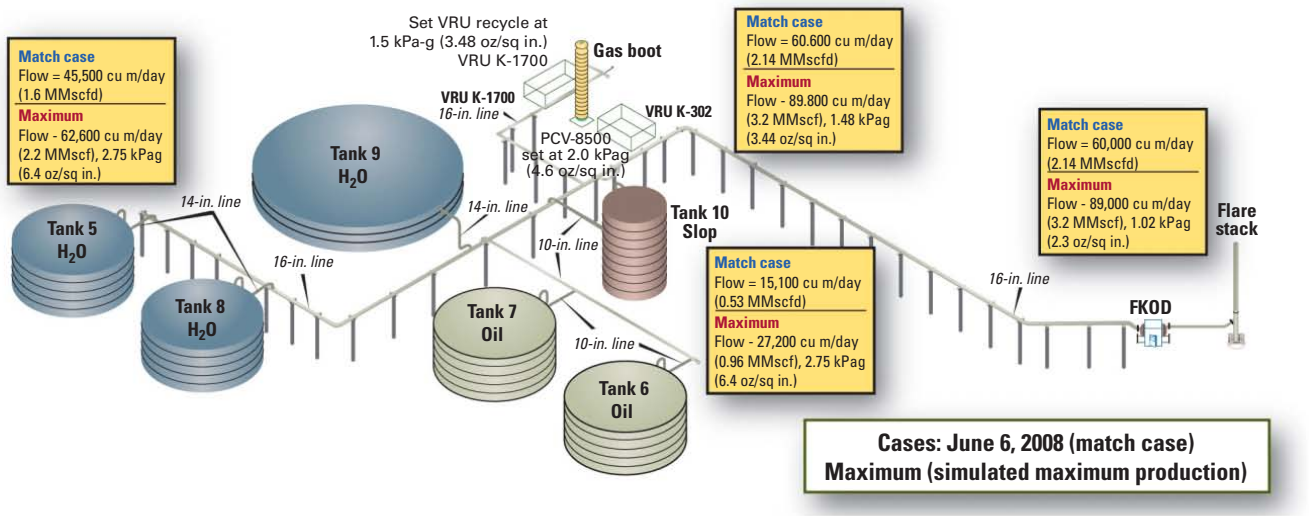
## STORAGE TANKS

Table 1

| Tank | Service fluid | Diameter, ft | Height, ft | LSHH, ft | Capacity, cu m | Capacity, bbl | PSV Set Pr/Vac, (Press/Vac kPa-g) |
|---|---|---|---|---|---|---|---|
| 5 | Water | 57 | 24 | 22 | 1,590 | 10,000 | 3.45/–0.18 |
| 6 | Oil | 57 | 24 | 22 | 1,590 | 10,000 | 3.45/–0.18 |
| 7 | Swing | 57 | 24 | 22 | 1,590 | 10,000 | 3.45/–0.18 |
| 8 | Water | 57 | 24 | 22 | 1,590 | 10,000 | 3.45/–0.18 |
| 9 | Water | 99 | 24 | 24 | 5,240 | 32,943 | 3.0/–0.215 |
| 10 | Slop | 30 | 40 | 40 | 800 | 5,037 | 3.0/–0.215 |

## FLARE SIMULATIONS

Fig. 3




tanks (liquid) and the K-302 VRU.

The produced oil, swing, and slop tanks (T-6, 7, and 10) feed the K-1700 VRU.

The produced water tanks (T-8 and 9) feed the K-1700 VRU (vapor) and the water injection pumps (liquid).

Gathering lines collect the vapor off the tanks and feed it to the VRU preferentially. If the VRU becomes overloaded, the excess vapor goes to flare via a pressure control valve PV-8500. The last line-of-defense is the PVRVs on the top of the tanks that relieve vapor to the atmosphere.

The vapor-handling equipment operates as follows (Fig. 3):

- For controlling overpressure if

## MATERIAL BALANCE, JUNE 6, 2008

Table 2

| Stream | 4 | 17 | 20 | 23 | 28 | 35 |
|---|---|---|---|---|---|---|
| Vapor, fraction | 0.0083 | 0.0011 | 0.0417 | 1.0000 | 0.9931 | 1.0000 |
| Temperature, °C. | 25.0000 | 28.5592 | 46.6178 | 98.7327 | 45.0000 | 67.5176 |
| Pressure, kPa-g | 325.0000 | 3.0000 | 9.0000 | 213.000 | 212.1053 | 212.1053 |
| Flow, MMscfd | 1,232.6967 | 1,457.2273 | 14.8778 | 0.6204 | 1.6757 | 2.2846 |
| Liquid flow, US gpm | 5,721.3962 | 5,787.0741 | 786.9846 | 10.3021 | 19.1840 | 29.4405 |
| Gas flow , cu m/day | 3.4807E+07 | 4.11868E+07 | 420,502.5600 | 17,534.9118 | 47,362.4179 | 64,572.7938 |
| Liquid flow, cu m/day | 31,187.3438 | 31,545.3545 | 4,289.8546 | 56.1566 | 104.5720 | 160.4803 |
| Liquid flow, b/d | 196,162.1547 | 198,413.9707 | 26,982.3276 | 353.2141 | 657.7371 | 1,009.3890 |
| Mole weight | 20.6589 | 18.0577 | 214.7624 | 51.2564 | 42.9749 | 45.3491 |
| Mass flow, kg/hr | 1.26839E+06 | 1.31063E+06 | 159,142.6563 | 1,583.8403 | 3,586.8147 | 5,160.3335 |
| Energy, btu/hr | –1.97641E+09 | –2.34987E+09 | –1.34974E+07 | 544,523.3322 | 811,651.4358 | 1.37400E+06 |
| Energy, hp | –776,761.1769 | –923,534.8908 | –5,304.7024 | 214.0057 | 318.9910 | 540.0053 |
| Heat capacity, kJ kg-mole-°C. | 81.1973 | 77.6616 | 408.4262 | 81.9638 | 40.1531 | 50.4878 |
| Thermal conductivity, W/m-K | — | — | — | 0.0211 | — | 0.0199 |
| Mass density, kg/cu m | 306.4873 | 401.6519 | 174.2274 | 5.3735 | 5.2065 | 5.1058 |
| Cp/Cv | 1.11 | 1.12 | 1.02 | 1.11 | 1.26 | 1.20 |
| Viscosity, cp | — | — | — | 0.0112 | — | 0.0144 |
| Z_factor | — | — | — | 0.9697 | — | 0.9829 |
| Hydrogen, mole fraction | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Nitrogen, mole fraction, | 0.000154 | 0.000001 | 0.000014 | 0.000325 | 0.000710 | 0.000609 |
| $CO_2$, mole fraction | 0.008995 | 0.001606 | 0.023174 | 0.432117 | 0.932861 | 0.801565 |
| $H_2S$, mole fraction | 0.000166 | 0.000054 | 0.001199 | 0.016416 | 0.020029 | 0.019148 |
| Methane, mole fraction | 0.000491 | 0.000000 | 0.000257 | 0.005601 | 0.000068 | 0.001571 |
| Ethane, mole fraction | 0.000282 | 0.000000 | 0.001736 | 0.028655 | 0.000460 | 0.008119 |
| Propane, mole fraction | 0.000381 | 0.000000 | 0.008823 | 0.086947 | 0.001492 | 0.024705 |
| i-Butane, mole fraction | 0.000147 | 0.000000 | 0.006390 | 0.034791 | 0.000608 | 0.009894 |
| n-Butane, mole fraction | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| i-Pentane, mole fraction | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| n-Pentane, mole fraction | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| n-Hexane, mole fraction | 0.000097 | 0.000000 | 0.007615 | 0.004274 | 0.000076 | 0.001216 |
| N-Heptane, mole fraction | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| n-Octane, mole fraction | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| NBP[1]1_26, mole fraction | 0.002491 | 0.000000 | 0.162066 | 0.339817 | 0.005993 | 0.096674 |
| NBP[1]1_112, mole fraction | 0.002397 | 0.000000 | 0.196374 | 0.026221 | 0.000463 | 0.007460 |
| NBP[1]1_175, mole fraction | 0.001244 | 0.000000 | 0.102961 | 0.001042 | 0.000018 | 0.000296 |
| NBP[1]1_225, mole fraction | 0.001053 | 0.000000 | 0.087213 | 0.000080 | 0.000001 | 0.000023 |
| NBP[1]1_275, mole fraction | 0.000898 | 0.000000 | 0.074374 | 0.000004 | 0.000000 | 0.000001 |
| NBP[1]1_350, mole fraction | 0.001450 | 0.000000 | 0.120138 | 0.000000 | 0.000000 | 0.000000 |
| NBP[1]1_554, mole fraction | 0.002491 | 0.000000 | 0.206381 | 0.000000 | 0.000000 | 0.000000 |
| $H_2O$, mole fraction | 0.977265 | 0.998339 | 0.001285 | 0.023708 | 0.037221 | 0.028719 |

## MATERIAL BALANCE MAXIMUM CASE

Table 3

| Stream | 4 | 17 | 20 | 23 | 28 | 35 |
|---|---|---|---|---|---|---|
| Vapor, fraction | 0.0035 | 0.0009 | 0.0436 | 1.0000 | 0.9906 | 1.0000 |
| Temperature, °C. | 25.0000 | 29.7078 | 46.5030 | 97.1343 | 45.0000 | 68.5505 |
| Pressure, kPa-g | 325.0000 | 3.0000 | 9.0000 | 213.0000 | 212.1053 | 212.1053 |
| Flow, MMscfd | 1,885.9845 | 2,413.1906 | 21.3852 | 0.9320 | 2.2588 | 3.1696 |
| Liquid flow, US gpm | 8,594.3322 | 9,579.3292 | 1,119.3975 | 15.8066 | 25.8894 | 41.6116 |
| Gas flow, cu m/day | 5.33051E+07 | 6.82060E+07 | 604,427.7806 | 26,342.8597 | 63,842.7660 | 89,584.9244 |
| Liquid flow, cu m/day | 46,847.7246 | 52,216.9453 | 6,101.8381 | 86.1615 | 141.1229 | 226.8248 |
| Liquid flow, b/d | 294,662.8182 | 328,434.1426 | 38,379.3415 | 541.9389 | 887.6350 | 1,426.6825 |
| Mole weight | 20.3590 | 18.0520 | 212.0574 | 51.5808 | 43.0013 | 45.6915 |
| Mass flow, kg/hr | 1.91242E+06 | 2.16974E+06 | 225,869.5313 | 2,394.4797 | 4,837.8521 | 7,213.2285 |
| Energy, btu/hr | –3.04342E+09 | –3.88243E+09 | –1.91008E+07 | 827,499.8982 | 1.08357E+06 | 1.94408E+06 |
| Energy, hp | –1.19610E+06 | –1.52585E+06 | –7,506.9047 | 325.2196 | 425.8607 | 764.0533 |
| Heat capacity, kJ kg-mole-°C. | 81.0744 | 77.6713 | 403.4149 | 84.3246 | 40.3974 | 52.1833 |
| Thermal conductivity, W/m-K | — | — | — | 0.0209 | — | 0.0200 |
| Mass desity, kg/cu m | 503.9464 | 451.4494 | 166.5865 | 5.4447 | 5.2233 | 5.1327 |
| Cp/Cv | 1.11 | 1.12 | 1.02 | 1.11 | 1.26 | 1.19 |
| Viscosity, cp | — | — | — | 0.0108 | — | 0.0141 |
| Z_factor | — | — | — | 0.9672 | — | 0.9821 |
| Hydrogen, mole fraction | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Nitrogen, mole fraction, | 0.000100 | 0.000001 | 0.000022 | 0.000482 | 0.001206 | 0.001001 |
| $CO_2$, mole fraction | 0.004921 | 0.001400 | 0.022069 | 0.397429 | 0.935509 | 0.783549 |
| $H_2S$, mole fraction | 0.000072 | 0.000031 | 0.000735 | 0.009802 | 0.012468 | 0.011768 |
| Methane, mole fraction | 0.000321 | 0.000000 | 0.000393 | 0.008234 | 0.000111 | 0.002500 |
| Ethane, mole fraction | 0.000184 | 0.000000 | 0.002340 | 0.037425 | 0.000673 | 0.011484 |
| Propane, mole fraction | 0.000249 | 0.000000 | 0.009611 | 0.092813 | 0.001790 | 0.028568 |
| i-Butane, mole fraction | 0.000096 | 0.000000 | 0.005793 | 0.031143 | 0.000612 | 0.009594 |
| n-Butane, mole fraction | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| i-Pentane, mole fraction | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| n-Pentane, mole fraction | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| n-Hexane, mole fraction | 0.000063 | 0.000000 | 0.005392 | 0.003013 | 0.000060 | 0.000929 |
| N-Heptane, mole fraction | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| n-Octane, mole fraction | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| NBP[1]1_26, mole fraction | 0.002300 | 0.000000 | 0.177716 | 0.369795 | 0.007339 | 0.113970 |
| NBP[1]1_112, mole fraction | 0.002213 | 0.000000 | 0.193964 | 0.025811 | 0.000513 | 0.007956 |
| NBP[1]1_175, mole fraction | 0.001148 | 0.000000 | 0.101183 | 0.001021 | 0.000020 | 0.000315 |
| NBP[1]1_225, mole fraction | 0.000971 | 0.000000 | 0.085664 | 0.000078 | 0.000002 | 0.000024 |
| NBP[1]1_275, mole fraction | 0.000828 | 0.000000 | 0.073063 | 0.000004 | 0.000000 | 0.000001 |
| NBP[1]1_350, mole fraction | 0.001338 | 0.000000 | 0.118022 | 0.000000 | 0.000000 | 0.000000 |
| NBP[1]1_554, mole fraction | 0.002299 | 0.000000 | 0.202746 | 0.000000 | 0.000000 | 0.000000 |
| $H_2O$, mole fraction | 0.982895 | 0.998568 | 0.001288 | 0.022949 | 0.039697 | 0.028341 |

## WEYBURN BATTERY PRODUCTION

Table 4

| Stream | Total production | Regular reservoir | $CO_2$ injection reservoir |
|---|---|---|---|
| | cu m/day | | |
| $H_2O$ | 26,000 | 12,500 | 13,500 |
| Oil | 4,300 | 1,550 | 2,750 |
| Gas | 2.8 million | 200.000 (5.5% $CO_2$) | 2.6 million (82% $CO_2$) |

the VRU cannot keep up, at 2.0 kPa-g PV-8500 opens and directs gas to the low-pressure flare. If pressure exceeds 3.0 kPa-g, the tank PVRVs vent to atmosphere.

• In the case of under pressure if the VRU pressure drops below 1.5 kPa-g, the VRU recycle valve opens and the VRU discharge recycles to suction for balancing inlet flow deficiency. If pressure drops below 1.0 kPa-g, the tank PCVs open and feed fuel gas to adjust pressure. The last-line-of-defense is the PVRVs that allow air into the tanks below –0.18 kPa-g.

### Process design

The objective of the process design was to debottleneck the tank's vapor-handling equipment. The steps involved were:

1. Build a model of the Weyburn battery and vapor-handling unit. Note, the Oil & Gas Journal article (Nov. 16, 2006, p. 43) gave the composition of the oil and gas for the restaged compression and new pump installation.

2. Compare actual operating conditions (Tables 4 and 5), mainly the flow to the VRU, with the battery model in Step 1.

3. Match the battery model with the

## WEYBURN BATTERY PROCESS CONDITIONS

Table 5

| Operating conditions | Pressure, kPa-g | Temperature, °C. |
|---|---|---|
| Gas separator | 1,375 | 29 |
| FWKOs | 315 | 29 |
| Treaters | 205 | 45 |
| Gas boot @ 1.5 m oil elevation/gas phase | 40/20 | 38 |
| Oil tanks | 2 | 40 |
| $H_2O$ tank | 2 | 30 |

## VENTED FLOWS OFF TANKS

Table 6

| Case | Description | Flows, 1,000 cu m/day — VRU K-1700 flow (Stream 28) | Total tank gas (Stream 35) |
|---|---|---|---|
| 1. | 82% $CO_2$ full gas | 47.2 | 61.5 |
| 2. | 5% $CO_2$ for 200,000 cu m/day | 45.5 | 60.5 |
| 3. | 92% $CO_2$ full gas | 52.5 | 63.6 |
| Meter | Composition as Case No. 2 | 37 (avg)<br>42 (max) | n/a |

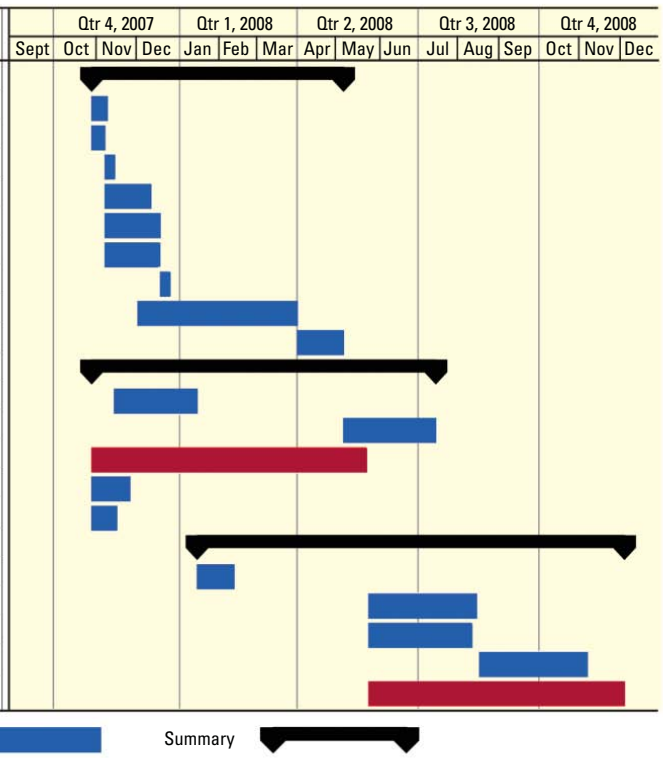
actual operating tank vented flow. Table 6 compares the K-1700 VRU actual flow vs. the simulations for different streams.

4. Determine if the existing flow (Stream 35, June 6, 2008, material balance = 64,600 cu m/day) does not exceed the capacity of running only the K-1700 VRU (capacity: 34,000 cu m/day (1.2 MMscfd) to 70,800 cu m/day (2.5 MMscfd)). If it does not exceed capacity (64,600 cu m/day), shut down the K-302 VRU and gas boot.

## LOW-PRESSURE FLARE PROJECT

Fig. 4

| Task name | Duration |
|---|---|
| **Engineering** | **137 days** |
| Process design | 10 days |
| P&IDs | 8 days |
| VRU meter IFC | 5 days |
| Civil IFA | 25 days |
| Mechanical IFA | 30 days |
| Electric/instrumentation IFA | 28 days |
| Spec equipment HAZOP | 5 days |
| Delay until Apr. 1, 2008 | 87 days |
| IFC all disciplines | 25 days |
| **Procurement** | **187 days** |
| VRU meter | 9 weeks |
| Flare FKOD | 10 weeks |
| Switchgear transfer | 30 weeks |
| Pipe valves fittings | 21 days |
| Electrical instruments | 15 days |
| **Construction** | **232 days** |
| Install VRU meter | 4 weeks |
| Tanks civil | 3 months |
| Supports civil | 56 days |
| Install piping | 60 days |
| Install electrical | 7 months |




5. Feed the maximum expected flows to the battery model. From this simulation, obtain the maximum flow to be handled by the vapor-handling equipment.

6. Design the gathering line size, PV-8500, VRU capacity, and flare for the maximum flows found in Step 5. Proceed with the detailed design, construction of the new vapor-handling unit after review and EnCana approval.

## *Operating condition match*

The simulation required installation of a meter on the discharge of K-1700 VRU. The meter provided data for matching actual flow rate with the simulation runs for three rates and conditions that may affect the results.

Table 4 summarizes the operating water, oil, and gas flows for the non-$CO_2$ flood reservoir vs. the $CO_2$ flood reservoirs and Table 5 provides the plant operating conditions for the simulations.

The simulations used these production flow rates and battery operating conditions for evaluating all potential flows off the tank vents. The three cases run were:

1. All gas to battery with 82% $CO_2$ (current $CO_2$ gas content vs. 92% in 10 years).

2. Only the 200,000 cu m/day of gas to the battery, specified as 5.5% $CO_2$ (gas produced from non-$CO_2$ injected reservoir).

3. All gas to battery with 92% $CO_2$.

## K1700 VRU FLOWS

Table 7

| Case | Fixed meter flow —— 1,000 cu m/day —— | Simulation flow | Difference, % |
|---|---|---|---|
| 1 (all 82% $CO_2$) | 42 | 47 | 12 |
| 2 (200,000 cu m/day 5.5% $CO_2$) | 42 | 45 | 6 |
| 3 (all 92% $CO_2$) | 42 | 53 | 25 |

## *Simulation results*

Table 6 shows the flow summary of simulation for Streams 28 and 35, respectively.

Stream 28 is the discharge of the K-1700 VRU. This flow corresponds to the flow through the newly installed flowmeter (FQIT-1709) that we tried to match and compare. Stream 35 is the total flow vented off all the production and slop tanks. Hence, these streams are the flow rates that all of the existing tank vapor-handling equipment must handle after the removal of the gas boot and K-302 VRU.

Table 7 compares the flows in each case.

From Table 7, we can conclude that the simulations were conservative. For the actual match Case 2, the simulation predicted 6% more gas than read by FQIT-1709 or the actual maximum-recorded flow.

The simulation for maximum flows

*The project included the installation of several access platforms on the six tanks (Fig. 5).*

involved extrapolating Case 1 (using 83% $CO_2$ gas analysis). Using this case ensures a 12% conservative number vs. 25% by using Case 3.

The maximum expected flow rates at the Weyburn battery in the maximum simulation are:

- 8.49 million cu m/d (300 MMscfd) associated and produced gas-83% $CO_2$.
- 6,000 cu m/day (37,740 b/d) oil production.
- 40,000 cu m/day (251,600 b/d) produced water.
- 12,000 cu m/d (75,480 b/d) source water.

From the simulations run for the maximum case, the total produced vent gas (Stream 35) is 89,600 cu m/day (3.2 MMscfd).

From the flow comparison of Table 7, we can normalize the flows to predict the maximum normalized flow.

It now follows that the vent flow predicted when the $CO_2$ in the reservoir is 92% (in 10-15 years) will be 1.075 × 89.6 = 96,600 cu m/day (3.4 MMscfd).

The evaluation included the creation and running of a model of the vapor-handling equipment pressure drops (Fig. 3).

The new flare pressure-drop simulations evaluated the maximum throughput through the VRU and flare. Fig. 3 shows the results of the maximum flow rate through the piping network.

The original pressure drop for the flow of 89,600 cu m/day provided a final pressure of 1 kPa-g at the flare tip and 1.48 kPa-g at the VRU K-1700. For sensitivity analysis, the simulation also included a run with a flow rate through the flare header and stack of 108,000 cu m/day (+10%). This resulted in a final flare-tip pressure of 0.76 kPa-g.

The FKOD and flare will see intermittently higher flow rates because the operation requires the addition of fuel gas for enhancing the heat content of the process gas to 6-8 MJ/cu m when the $CO_2$ content is greater than 87%. The fuel gas is added at the inlet to the FKOD.

At 92%, a maximum of 10-20% fuel gas must be added to get to 6-8 MJ/cu m. Hence for 96,600 cu m/day, the process would need an additional 10,000-20,000 cu m/day. The highest flow through the FKOD and flare will be 98,000-116,000 cu m/day (4.1 MMscfd).

## Equipment process design

The main items required for the low-pressure vent system included vent-gas piping, FKOD, flare stack, VRU, flare-gas pressure control valve PV-8500, and flare fuel-gas makeup valve to adjust blended gas to 6 MJ/cu m.

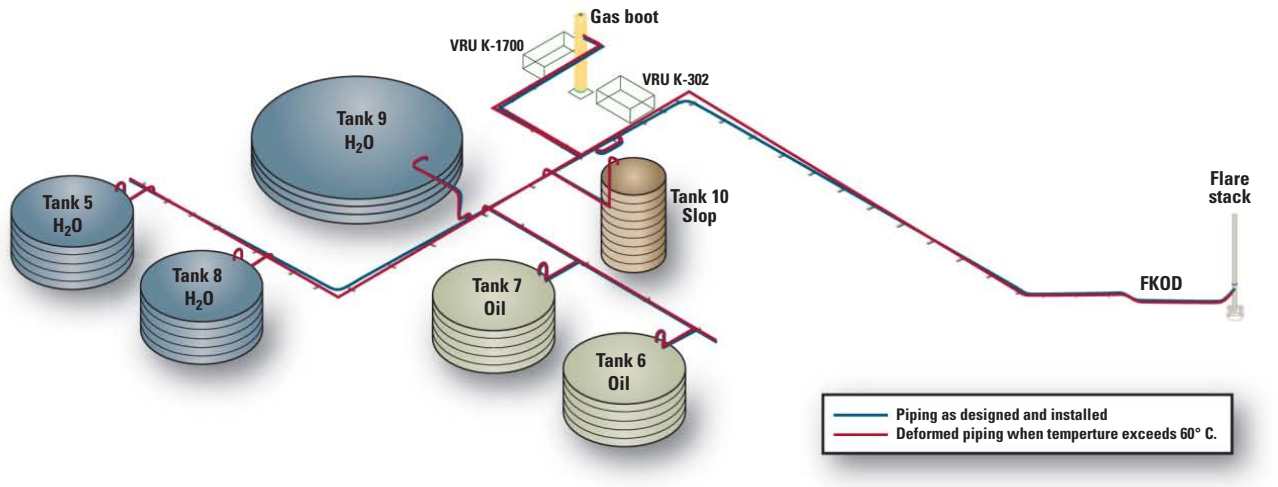
The design sized the vent-gas piping per the maximum tank vent-gas flows predicted by the simulations. The evaluation simplified the simulations conservatively to flow the total tank vent gas from the farthest water or oil tank. The water tank vent would start at Tank No. 5, through the NPS 14-in. line off the top flange, and through the NPS 16-in. line to the junction of oil tank Nos. 6 and 7.

The oil tank vent would start at Tank No. 6 NPS 10-in. top flange line and join the NPS 10-in. common oil-vent header. The water tank vent gas and the oil tank vent gas join at the NPS-10-in. oil tank gas vent and the NPS 16-in. main header. Tank No. 10 is a rework tank and produces insignificant vapors.

The gas in the combined NPS 16-in. vent header can go now to the VRU if the pressure is less than 2 kPa-g or to

## PIPE STRESS ANALYSIS

Fig. 6




## MAXIMUM NORMALIZED FLOW

Table 8

| Case | Normalization factor for, 1,000 cu m/day | Quotient (flow) | Value |
|---|---|---|---|
| 2 Sol. gas 5% $CO_2$ | Fixed meter flow | Meter/Case 2 | 42/45 = 0.913 |
| 1 Sim 82% $CO_2$ | 82% Stream 28 (June 2-6, 2008) | Case 1/Case 2 | 47/45 = 1.044 |
| 3. Sim 92% $CO_2$ | 92% Stream 28 (June 2-6, 2008) | Case 3/Case 1 | 53/47 = 1.128 |
| **Product of three values** | | | **1.075** |

the flare knockout and ultimately to the flare if the pressure is more than 2 kPa-g.

When the heat content of the process vent gas drops to less than 6 MJ/cu m, the process requires the addition of fuel gas so that the gas has the minimum 6-8 MJ/cu m required for complete combustion in the John Zink flare. The piping does not have to handle the added fuel gas. The flare knockout and flare can handle the added 14,200-28,300 cu m/day of additional gas.

The evaluation sized the flare knockout drum, designed by Falcon, at 1.83 m diameter by 3.05 m with NPS 16-in. inlet and outlet connections. The design includes heating and instrumentation for control of pumping out liquids.

The flare stack was a John Zink 50-ft, self-supported, Rimfire, high $CO_2$, high-destruction efficiency unit.

The existing VRU is a Fuller Kovalko CC-300 compressor capable of 1.2-2.47 MMscfd with 1.6 SG gas at atmospheric pressure suction and 400 kPa-a discharge. It could operate until it gets fully loaded. After that, EnCana will twin this unit to have ample capacity to compress the 3.2 MMscfd at maximum flows.

The flare-gas pressure control valve PV-8500 is a Fisher V-ball NPS 12-in. for handling 100,000 cu m/day (3.5 MMscfd) at 2 kPa-g.

The flare fuel-gas makeup valve to adjust blended gas to 6-MJ/cu m (FYV-1043) is an NPS 2-in. Fisher 657-40 D body for flow of 5,700-28,320 cu m/day (0.2 to 1 MMscfd).

### Cost, schedule

The project stopped and started several times for incorporating a separate project to build tank access to the top of all the tanks and to avoid winter construction. EnCana justified the project economics as required for debottlenecking the flare and header to avoid atmospheric tank venting.

Table 9 shows the projects costs.

The construction costs were 59% (they usually are 50%) of the total costs because of the difficulties with construction. The tank construction delays were due to:

- Interruptions of the work at the tank site for frequent tank venting through PVRVs. This affected both civil and piping work.
- The need to empty, neutralize, and isolate each tank during the tie in.
- Conducting the work with both flares operating simultaneously to avoid a long production shutdown.
- The 30-week delivery of the electrical switchgear and transformer. This delayed electrical piping interfaces such as heat tracing.
- Expensive demolition of existing flare and ancillaries, which required intermittent work.

Fig. 4 shows the project schedule. Note that the project was put on hold from December 2007 to Apr. 1, 2008, to avoid winter construction. The strategy worked relatively well because construction was during mostly warm weather. Unfortunately, the intricacy of interfacing the civil and piping work with the operating problems made simple tasks take double the time.

### Engineering, construction

The project required extensive civil

mechanical drawings, as follows:

- Foundation drawings for the pipe rack, FKOD, flare, and tank platforms. Fig. 5 shows a specific platform view of the several platform installations required on the six tanks. The platform gives complete access to the top of the tanks.
- Piping drawings including piping and instrumentation diagrams, plot plans, materials isometrics, and 3D new piping and tank detail.
- FKOD skid layout of equipment and bill of materials.

The construction involved:

- Installation of a gas-assist type flare stack.
- Skidded flare knockout drum (FKOD).
- New flare header line (16-in. NPS).
- Replacement vent lines off the tank, vent nozzles on the tank roof with an upsized vent header running to the existing VRU compressors.
- New fuel-gas header line with individual tie-off piping runs supporting the new low-pressure flare.
- New drain line from the new FKOD to the tanks.
- Demolition, removal of the existing old low-pressure flare stack, buried low-pressure FKOD, buried portion of the low-pressure flare header line, and low-pressure vent header lines off the tanks.

Additional work included isolation, cleanout, and proper in-place abandonment of any ancillaries, removal of the vent header running to the existing VRU and compressors, and removing the utility portion of the low-pressure flare line.

## Pipe stress analysis

Fig. 6 shows the deformation of the installed piping after the flow was in steady-state operation at 50-60° C. temperature change.

It is critical not to overstress the system. The tank nozzles on the tank roof provide an example. These nozzles are between NPS 10 and 12 in.

The roof membrane is 3/16-in. WT. The nozzles cannot tolerate any significant moments because they would easily deform or fail the roof membrane. It took considerable effort to minimize the moments with guides and anchors.

### PROJECT INSTALLED COSTS

Table 9

| | Cost, $1,000 |
|---|---|
| Equipment materials: | |
| Instrumentation and control valves | 84 |
| FKOD | 68 |
| Low-pressure JZ Rimfire flare | 195 |
| VRU flowmeter | 16 |
| Electrical materials | 32 |
| Pipe valve fittings | 322 |
| **Subtotal equipment materials** | **717** |
| Construction: | |
| Civil for low-pressure flare | 173 |
| Civil for tanks | 189 |
| Mechanical low-pressure flare | 867 |
| Mechanical tanks | 330 |
| Electrical instrumentation | 369 |
| PLC | 35 |
| Supervision, quality control, transport | 145 |
| **Subtotal construction** | **2,108** |
| Other: | |
| Engineering, surveying, regulatory | 516 |
| Overhead | 242 |
| **Subtotal other** | **758** |
| **Total** | **3,583** |

## Electrical design, construction

The electrical drawings consisted mainly of controlling the FKOD liquid level. The turning on and off the pump would control a certain level.

A second component of the design was electric tracing all the vent lines and FKOD shell to keep them from freezing.

The last component included the design of gas detection, ventilation, and lighting.

Prewiring all electrical and instrumentation lines into locally mounted junction boxes simplified construction. Thus the majority of field electrical and instrumentation work was installation of cables and conduits from junction boxes to master control centers and programmable logic control panels. Electric heat tracing was installed in the same fashion.

## Results

The VRU meter readings were within 6% (lower) of values predicted in the simulations. This implies that the Peng Robinson Sour equations have enough accuracy for predicting $CO_2$ recycle gas behavior in oil and water.

The simulations with the maximum flow rates accurately predicted the tank vented flows to the VRU. Thus, the sizing of the tank vent piping and associated handling equipment is reliable.

By twinning of the existing VRU K-1700, the two VRUs can easily handle the maximum predicted flow rates of 109,000 cu m/day. One VRU can handle 2.0-2.5 MMscfd or 57,000-71,000 cu m/day. This value is from a data sheet for a Fuller Kovalko CC-300 VRU.

EnCana operations reported that after installation of the low-pressure flare system, they did not encounter any problems with overpressure or flow surges in the VRU or flare.

## Acknowledgment

The author expresses his thanks to EnCana's lead operations engineer Gerry May, who was the project manager for the upgrading work. ✦

**The author**

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REFINERY GASES—
Conclusion

# Specialty gases assist product quality, emissions compliance

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This article is the third and final in a series (OGJ, Nov. 23, 2009, p. 50; Dec. 7, 2009, p. 48) on the effects of recent developments on refineries and their use of gases to meet new regulatory and legislative requirements while avoiding major investments.

This article addresses refineries' use of specialty gases, which are used in small quantities but are nevertheless of high value for refineries.

These gases especially help the refinery to ensure the correct product quality and meet regulations with respect to emissions into the environment.

Gas production plants are also discussed.

## Specialty gases in refineries

Specialty gases are either very pure gases, rare gases, or gas mixtures of very high mixing accuracy used in such demanding applications as quality measurement for products and off-streams in the field and in the labs. Besides calibration purposes, this includes application as utilities for operation of such analytical devices as gas chromatographs.

These gases play an important, though not easily visible part in refineries, contributing to the optimum economy of a refinery.

Major specialty-gas companies can provide the complete range of specialty gases, both standard and tailored products, plus the services and equipment necessary for efficient use. In large companies, specialty gases are based on a long history of expertise and performance. These companies generally know or can determine what refiners need.

## Applications

The most commonly known uses for gases in a refinery are in hydrogenating and inerting, possibly also in welding, since these are situations in which the gas is seen in operation. But specialty gases—although unseen—are used somewhere in almost every product chain.

For instance, measuring gasoline quality checks the result with the help of instruments calibrated with specialty gas mixtures. Carrier gases in gas chromatography are high-purity specialty gases. In emission control, specialty gases help to detect hazardous materials. During a turnaround of, for example, a distillation tower, one needs a specialty gas mixture for leak detection.

Following are some examples of application fields in which specialty gases and expertise in refining processes can make a big difference in economy.

## Gas chromatography

Prominent among the analytical instruments used in refineries are gas chromatographs. In these devices, carrier gas transports gas components through the separation column and to the detection system. For this purpose, high-purity gases used are typically of a 5.0 purity, that is, more than 99.9990% purity. Especially used are $N_2$, $H_2$, argon, and helium of purity 5.0.

Of primary concern is the absence of specific trace components in these gases. This quality normally can be guaranteed by the gas supplier. Some detection systems call for dedicated sup-

*Here is an example of a steam reformer, in the Milazzo refinery, Sicily (Fig. 1).*

*This PSA hydrogen plant is at the Leuna refinery in Germany (Fig. 2).*

ply of gases as utilities. For example, flame ionization detectors in refineries analyze hydrocarbons that are burned in these detectors by addition of fuels, such as $H_2$ and an oxidant, typically artificial air. Even traces of hydrocarbons in this air stream would disturb the readings of the FID.

Controlling the quality of a product, especially concentration, involves comparing it with a specified gas mixture, the calibration gas. Such highly defined gases are needed not only for gas chromatography but also for calibration of other analytical instruments as, for example, ultraviolet or infrared spectrometers. Tailored gas mixtures are provided according to the specifications of the refinery, especially mixtures of hydrocarbons in $H_2$, $H_2S$ in $N_2$, hydrocarbons in butane, a specified amount (in parts per million) of CO in helium, mercaptans in helium, hydrocarbon mixtures in CO, and hydrocarbon mixtures in propane.

In addition, gases are provided for measurement during production, as in process control. These include, for example, mixtures of hydrocarbons in methane or in $H_2$, methane in $CO_2$, a specified amount (ppm) of $O_2$ in $N_2$, a specified amount (ppm) of CO in $N_2$, and $SO_2$ in $N_2$.

## Leak detection

Many systems in a refinery are checked for leaks with helium or helium mixtures. Tight systems are essential in any refinery section, whether piping in a sulfur-recovery unit or fractionator column of a fluid catalytic cracker. A leak of poisonous gas from a Claus plant or an explosive gas from a FCC unit can be disastrous.

Leak-testing procedures often use a gas mixture of helium in nitrogen. The helium passes through any leaks and is detected on the outside by a "sniffer," a mass spectrometer.

## Stack control

Refineries must strictly control their emissions to the atmosphere. Chief among the toxic and hazardous pollutants are $SO_2$, $CO_2$, $H_2S$, and $NO_x$; but also CO must not be neglected.

The concentration of this highly toxic compound is always of concern when hydrocarbons are burnt, as in boilers. For example, when the regenerator of an FCC unit is operated in partial-burn mode and corresponding effluent gas is heavily loaded with CO, the efficiency of its combustion to $CO_2$ is especially important. For incinerator systems generally, a certain surplus of oxidation air is a precondition for proper operation and therefore must be controlled.

For example gases containing appreciable amounts of so-called "totally reduced sulfur compounds," such as COS, $CS_2$, and especially $H_2S$—typically stemming from Claus units—are not only toxic but also prone to cause odors. Therefore such gases must be incinerated to gain exclusively $SO_2$ as a sulfur-bearing emission component.

Correspondingly, for control of stack-gas quality, not only $H_2S$ and $SO_2$ are measured but also oxygen content. Corresponding $O_2$ on line analyzer—often on the basis of a paramagnetic measuring principle—for the sake of precision must be calibrated with a gas mixture of $O_2$ in nitrogen that resembles the expected composition of the required $O_2$ content of the emission stream, that is, only a few percent of $O_2$ per volume.

Sometimes analysis of emissions takes place at the top of a stack requiring calibration at that point. As climbing a stack carrying a bulky and heavy gas bottle is hard and risky, a small and easily portable calibration gas cylinder was developed for that purpose.

One widely used technique for measuring gaseous emissions is gas chromatography with a suitable detector, as the FID described previously.

Another type of detector for monitoring hydrocarbons is the photoionization detector. The PID has the advantage of requiring no fuel gas, such as hydrogen. But the disadvantage is that it is insensitive to $C_1$-$C_3$ saturated hydrocarbons because these are quite stable compounds that are not easily ionized. When looking for traces of sulfur-containing compounds, for example, a flame photometric detector is suitable. The electron-capture detector is particularly sensitive to halogenated compounds, which in general are easily charged by electron addition.

A gas chromatograph plus mass spectrometer as a detection system is frequently used for identifying compounds in exhaust gases because this combination is not only capable of

analyzing small traces but also covers a wide range of chemical species to be measured.

## Vapor emission control

Also of concern are volatile organic substances (characterized by high vapor pressure and low water solubility) typically emitted from storage tanks. Every refinery has its own tank farm whose tanks contain crude oil and such refined products as gasoline, diesel, and kerosine.

*This cryogenic air separation unit at the Leuna refinery produces 1,500 tons/day of gaseous oxygen and 2,700 tons/day of nitrogen, plus 400 tons/day of liquid oxygen, nitrogen, and argon (Fig. 3).*

During the filling of these tanks, air or inert gas saturated with hydrocarbon vapors necessarily emanates from the tanks. Furthermore some of these products have a high vapor pressure, which also results in vapors being released. These substances pose potential safety and environmental hazards and must be monitored.

To determine their content, they often are analyzed by a gas chromatograph-FID combination because they are hydrocarbons. The standard against which the offgas is measured is artificial air produced as a specialty gas with a precisely adjusted content of the pollutants in question, often in the parts-per-billion range.

## Gas-production plants

Gases used in major quantities in refineries are hydrogen, nitrogen, and oxygen; all three can be produced in refinery-based gas production plants.

Hydrogen can be produced from practically all hydrocarbons, methane up to naphtha, heavy oil, asphalt, or coal. The processes involved may be steam reforming, autothermal reforming, gasification, and prereforming.

Fig. 1 shows an example steam reformer at the Milazzo refinery in Sicily; Fig. 2 shows the hydrogen pressure-swing adsorption plant at Total's Leuna refinery in Germany.

A particularly efficient reactor with internal cooling was developed by Linde AG 15 years ago for the CO shift, in which carbon monoxide and water react to produce hydrogen and carbon dioxide. One such reactor is more efficient and cheaper than a series of conventional, uncooled reactors with heat exchangers in between for temperature control.

This new reactor type has been used many times. The process yields residual carbon monoxide of less than 0.2% vol/vol even from high concentrations of carbon monoxide. A downstream PSA plant concentrates the hydrogen from the CO-shift converter.

Such PSA plants can be large. Linde built the largest hydrogen PSA unit in the world, for example, at the Ssang Yong Oil Refinery Corp., Onsan, Korea. It recovers hydrogen from two 175,000-standard cu m/hr streams.

Control of the switching valves in a PSA unit is crucial. Linde PSA units can take individual adsorbers or groups of adsorbers out of service, while the rest of the plant can continue to operate. This permits maintenance during operation, such as repair of valves that are no longer sufficiently gastight. Thus the availability of the PSA plant is practically 100%.

For smaller amounts of hydrogen that may contain impurities, there is the option of membrane units for hydrogen separation.

The quality of the hydrogen produced ranges from only roughly purified crude hydrogen to highly pure hydrogen for the electronics industry, at more than 99.999999% purity.

To produce oxygen or nitrogen, air-separation units are employed. Cryogenic air separation, invented 1895 by Carl von Linde, has been developed continually since then. Fig. 3 shows the Leuna air separation unit, which supplies gases to Total's Mitteldeutschland refinery.

The largest air-separation plant for nitrogen production so far was built by Linde. It was shipped to Cantarell, Mexico, for enhanced oil recovery (nitrogen injection). Five plants operate there, each at 500,000 scm/hr air intake, producing 335,000 scm/hr nitrogen at 120 bar. At the small end, standard cryogenic air-separation plants are available on the market with only 1,000 scm/hr air throughput to recover about 700 scm/hr nitrogen or about 200 scm/hr oxygen.

While the cryogenic units serve to produce highly pure oxygen and nitro-

gen, PSA plants can be used if less purity is required for gas throughputs in the range up to about 5,000 scm/hr.

The accompanying table summarizes the optimal ranges of use for the various gas generation systems for most applications.

**TYPICAL RANGES OF APPLICATION FOR GAS GENERATOR UNITS**

| Gas | Gas volume, std. cu m/hr | Purity, % vol/vol | Unit type | Comments |
|---|---|---|---|---|
| $H_2$ | up to ≈100 | >99.9 | Trailer up to about 400 kg $H_2$ | Gaseous |
| | 1,000 to 100,000 | >99.9 | PSA | Recovery from refinery residual gases |
| | 1,000 to 200,000 | >99.9 | PSA | Gas from steam reformer |
| | 20,000 to 100,000 | >99.9 | PSA | Gas from partial oxidation of oil |
| $N_2$ | 0 to ≈1,000 | >99.5 | Liquid supply from tank | Also for highly variable usage |
| | ≈1,000 to 5,000 | >99.0 | $N_2$-PSA | Load range typically 30-100% |
| | 1,000 to 300,000 | >99.5 | Cryogenic air separator | Load range typically 30-100% |
| $O_2$ | 0 to ≈1,000 | >99.5 | Liquid supply from tank | Also for highly variable usage |
| | ≈300 to 5,000 | <95.0 | $O_2$-PSA | Load range typically 30-100% |
| | ≈200 to 100,000 | >99.5 | Cryogenic air separator | Load range typically 30-100% |

## *On site supply*

Refiners have several options to fulfill higher industrial gas needs. Of course, gas production plants can be bought from competent suppliers. That necessarily means that the complete investment shows up in the balance sheet of the refinery. In addition, operation and maintenance costs have to be borne by the refinery.

All this is conventional procedure with advantages and disadvantages. The main disadvantage certainly is that refiners are not specialized in gas plant operation. Therefore reliability of the plants tends to be lower than optimum and the cost higher. But there is an alternative which gains more and more friends among the refining community: "on site supply."

The basic idea behind on site supply is that a gas company builds, owns, and operates the gas production plant for the refinery and the refiner receives the gas as a utility so that it can concentrate on its core business, making fuel.

For on site supply of industrial gases, the gas supplier takes on the investment for the plant and the operating risks. The refineries provide the necessary working materials, such as methane for a steam methane reformer or cooling water for heat exchangers. The result is that the refinery receives the required gases and bears no obligation for the operation of the gas generation facility.

This arrangement affords the refinery several advantages:

- The gas plant is operated by a gas company for which this is core business. The gas companies have experience from operating many such plants. The on site concept secures this experience for the refinery, and as a result the refinery has a reliable gas supply and can concentrate on its own operations.
- The gas supplier takes on the investment in the gas plant. The refinery has less capital tied up for industrial gases.
- The gas company can build the gas plant according to its standards, allowing repeat engineering, which saves money. In addition spare parts can be standardized and stored centrally for specific types of gas plants. This also reduces cost so that gas from an on site plant is usually cheaper compared with a gas plant owned by the refinery.
- With on site supply, the gas operation is usually not part of the refinery balance sheet. Thus the refinery's equity ratio improves and can foster a better rating. In turn the refinery may enjoy improving financial flexibility for this site.

The proper contractual arrangement is critical of course. The accounting practices that apply at the refinery location, such as Generally Accepted Accounting Practices in the US or International Accounting Standards in the EU, have a major influence. This point can only be mentioned here, not discussed in detail, as conditions depend on each location.

The gas company owning the on site plant takes on the risk of a high capital investment. The term of the contract with the refinery will be based on the expected service life of the gas plant, usually 15 years. That time frame can be calculated shorter for small, standardized units, such as containerized nitrogen plants. These units can be reused more easily for other customers after the contract expires.

Because oxygen and nitrogen are usually not required in liquid form, on site plants do not involve expensive liquefaction energy for production. Without truck shipment, costs are lower and the operation is "greener." Hydrogen, too, is used only as a gas in refining applications so that expensive liquefaction is not required in an on site plant.

Beginning in the 1980s, the concept of on site supply began to spread. It succeeded especially in the industrialized countries where it largely displaced the old regional gas distributors in many areas.

Under favorable conditions, conversion to on site supply can reduce gas costs, often by more than 10%. ✦

## Correction

Table 1 of "REFINERY GASES—1: Hydrogen, nitrogen assist compliance with new, tougher environmental regs," M. Heisel, B. Schreiner, and W. Bayerl (OGJ, Nov. 23, 2009, p. 50), inadvertently omitted data for 2009 diesel fuel sulfur content: <10 ppm.

# Self-resonated jet technology improves cavern construction

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Using a self-resonated cavitation jet can increase the salt dissolution rate and improve the efficiency of natural gas storage cavern construction, particularly in bedded (vs. domed) salt deposits. The rapid solution-mining tool can increase salt production sharply compared with conventional solution mining, accelerating storage construction. The tool also reduces debris settling in the bottom of a cavern.

## Background

China's second West-East natural gas pipeline is under construction. Work includes associated underground gas storage salt caverns. Construction of salt caverns requires finding an appropriate salt dome or salt bed, drilling a well into the formation, and injecting fresh water to dissolve and extract a certain amount of salt to get a specified volume and shape.[1] Bedded salt deposits are widespread and used as much or more than diapiric salt bodies to host storage facilities. These deposits are layered and interspersed with non-salt sedimentary materials such as anhydrite, shale, dolomite, and limestone.[2]

Solution mining bedded-salt formations by conventional methods is difficult. Dissolving and shear stress of circulated fluid break thin, weak interlayers, but thick and hard interlayers are difficult to break efficiently, slowing the dissolution rate and changing the salt cavern's shape. The erosion of interlayers also generates insoluble debris that settle at the bottom of salt cavern.

Too many interlayers will deposit much of the debris at the bottom, reducing the effective dissolution volume of the salt cavern, especially in the pocket construction stage, forcing relocation of the mining pipe to a higher position to achieve rapid solution mining and optimal cavern shape.

This article details a new method of rapid solution mining via numerical simulation and field testing of a new self-resonated cavitation jet.

## Self-resonated jet

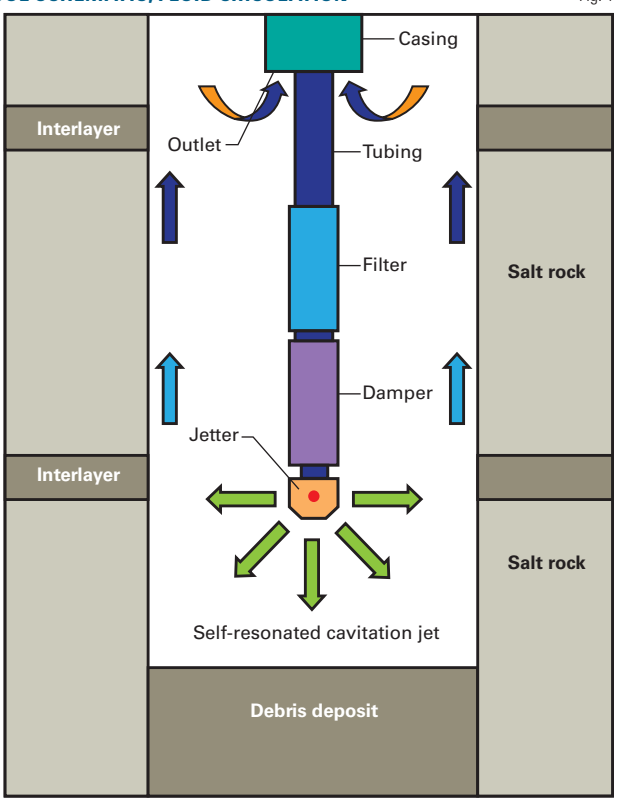
The self-resonated cavitation jet has strong pressure oscillation and high cavitation inception characteristics.[3] A continual jet using the fluid transient theory describing the transition of small turbulent wave in the pipe, and the principle of fluid self-sustained oscillation of hydroacoustics modulates the jet.[4] In conditions of ambient and atmospheric pressure, the new jet has stronger cavitation, higher destructive power, and better application effect than the conventional continuous jet.[5]

The characteristics of self-resonated cavitation jet and the technique of damping rotation control have led to development of a rapid solution-mining tool for bedded salt mining by China University of Petroleum. Fig. 1 shows the schematic of the tool and fluid circulation.

The tool consists of a filter, a rotation damping controller, rotary jetter, and self-resonated cavitation nozzles. The tool connects to the tubing and travels into the salt caverns. Fresh water pumped through the tubing, filter, damper, and jetter generates multiple self-resonated cavitation jets.

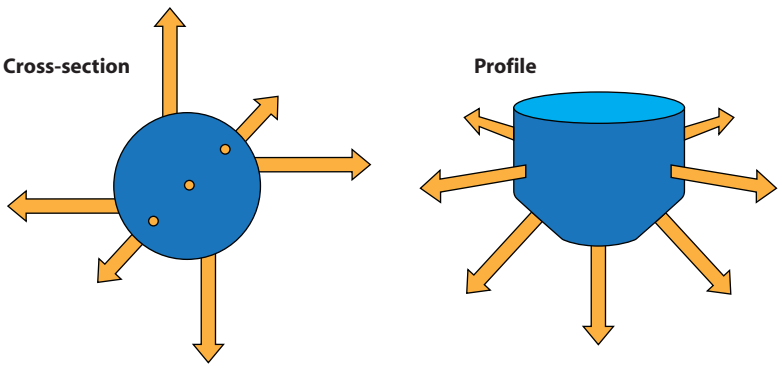
Four lateral high-pressure water jets drive the tool and rotate it to impact the salt rock and interlayers uniformly, generating a strong helical flow

TOOL SCHEMATIC, FLUID CIRCULATION Fig. 1



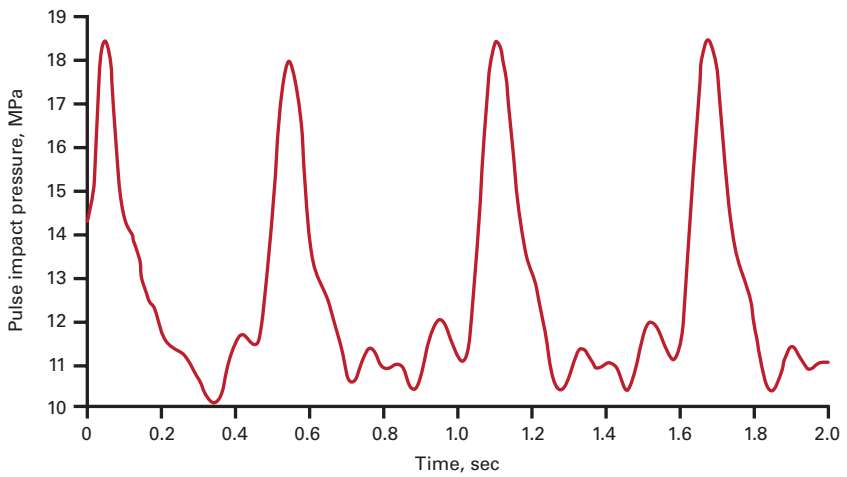
## NOZZLE DIRECTIONS

Fig. 2




## CAVERN WALL IMPACT PRESSURES

Fig. 3




in the cavern (Fig. 2). The three directional jets pointed downward rotate and impact the debris settlements in the bottom of the cavern to lift it and suspend it in the helical fluid. After salt dissolution and diffusion, the fresh water becomes brine and is circulated out of the cavern with suspended debris through the annulus between tubing and casing.

## Physical effects

The rapid solution-mining tool can generate four compound physical effects: self-resonated cavitation jet erosion, supersonic wave, helical flow, and forced circulation.

- *Self-resonated cavitation jet erosion.* The self-resonated cavitation jet has intense pressure oscillation and better rock erosion effectiveness than standard jets.[6] At atmospheric pressure, its rock erosion rate measures two to four times higher than conventional jets.[7] Fig. 3 shows the effect of four powerful hydraulic pulses on the wall at every circle. Each self-resonating cavitation jet is a high-frequency oscillating jet.

Repeated powerful pulsed impacts produce microfractures on the wall and sometimes the salt rock and interlayers can be broken directly. The spreading microfracture and penetration increase the rate of salt dissolution.

The self-resonated cavitation jet also has a high cavitation bubble inception ability. The collapsing cavitation bubble produces transient pressure 8.6-124 times higher than the jet impact for a few microseconds and can also break the rock directly.[8]

- *Supersonic wave.* The self-resonated cavitation jet can also produce high frequency, high-radiation supersonic waves, creating lower brine viscosity, better flow ability, and a higher mass-transfer rate.[9] The noise wave impact on the salt rock surface also causes fatigue fracture which can enhance the salt dissolution rate. The energy from the noise transferring to the salt surface can also potentially create severe vibration and accelerate salt diffusion.
- *Helical flow.* The action of the lateral water jets rotating as four agitator arms (Fig. 4) rotates the fluid in the cavern as a helical flow with a vertical rotation axis. The fluid velocity on the surface of the salt rock increases and the flow direction can be changed, enhancing the mass transfer of salt molecules near the wall. The process also changes the brine's flow pattern in the cavern, increasing the convective diffusion of saturated brine.

The rotation jets and helical flow also improve efficiency of debris cleanout and reduce settlement in the bottom of the cavern. Debris broken from the interlayers suspends and moves out with the circulated fluid immediately, and debris settled in the bottom is lifted and suspended by the rotary impact of the three downward directional jets, moving out with the helical fluid.

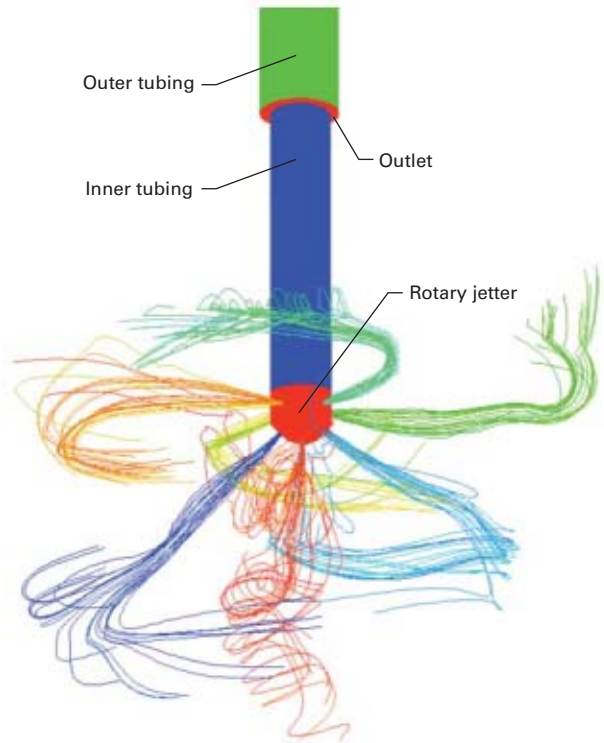
- *Forced circulation.* The high-pressure water jets force fresh water to the rock surface quickly. This forced circulation changes the horizontal and vertical distribution of concentration of brine and enhances the convective diffusion of saturated brine near the wall, improving the salt-dissolution rate dramatically.

## Numerical simulation

A numerical simulation carried out with a 3D cylinder model (5 m high by 2 m diameter) researched the helical flow and efficiency of debris cleanout on the basis of two-fluid Euler-Euler model and RNG $\kappa - \varepsilon$ model. Field operations and hydraulic parameters design led to 177.8 mm (ID) casing and 114.3 mm (OD) tubing being chosen as the solution-mining pipes and 6 mm being set as the optimal orifice diam-

## HIGH-PRESSURE JET MOTIONS

Fig. 4




eter for the self-resonated nozzles.

Fig. 5 presents the path lines of high-pressure water jets and contour of tangential velocity of circulated fluid in the salt cavern. The rapid-solution-mining tools easily create helical flow, which could increase the salt-dissolution rate and cleanout efficiency of debris. The maximum tangential velocity (3 m/sec) occurs near the mining pipe and decreases as the radial distance increases.

Fig. 6 shows the contour of debris volume fraction at different cleaning times. The volume of debris settled at the bottom decreases over time, instead spreading all over the cavern as the lift force overcomes gravity.

Flow rate strongly affects the efficiency of debris cleanout (Fig. 7), the cleanout efficiency increasing as flow rate increases and reaching 85% at 57.3 cu m/hr after 10 min. The diameter of debris and rotation speed of the jetter also influence cleanout efficiency.

Fig. 8 shows sharp decreases in efficiency as debris diameters increase. Maximum and minimum cleanout efficiency occurs at 80 rpm and 60 rpm, respectively. In this condition, debris bigger than 0.7 mm becomes difficult to clean out due to inadequate lift, nearly eclipsing any difference in efficiency caused by the jetter rotation speed. In this simulation the jetter optimal rotation speed measures 80 rpm and a maximum efficiency of 79.2% occurs with a diameter of 0.1 mm after 10 min operation.

This simulation suggests that, when constructing a pocket, the rapid-solution-mining tools with a self-resonated cavitation jet can generate helical flow, enhance the efficiency of debris cleanout, and reduce settlements in the bottom of a salt cavern.

## Field test

The rapid-solution-mining tool helped build a pocket at well J1, Jintan, Jiangsu province. Salt thickness measured 241 m, while total depth from the surface to the top and bottom of the pocket measured 945 m and 1,186 m, respectively. Material analyses showed the formation contained about 13.4% insoluble materials, consisting of interlayers about 4.2 m thick. A 177.8 mm (7 in.) casing and 114.3 mm (4.5 in.) tubing served as the middle pipe and central pipe, respectively. Well C5, developed by the conventional solution-mining method, served as a control well. The chemical properties of the produced brine, bed thickness, and total depth of the salt formation in both C5 and J1 were identical.

Fig. 9 compares the salt production rates from C5 and J1, showing a much higher rate for J1. Fig. 10 compares accumulated salt production for both wells. Accumulated salt production over the initial 11 days of C5 well was 376.0 tons, while J1 well produced 866.7 tons, a 130.5% greater rate, demonstrating the greater capabilities of the rapid solution-mining tool with self-resonated cavitation jets.

## Acknowledgment

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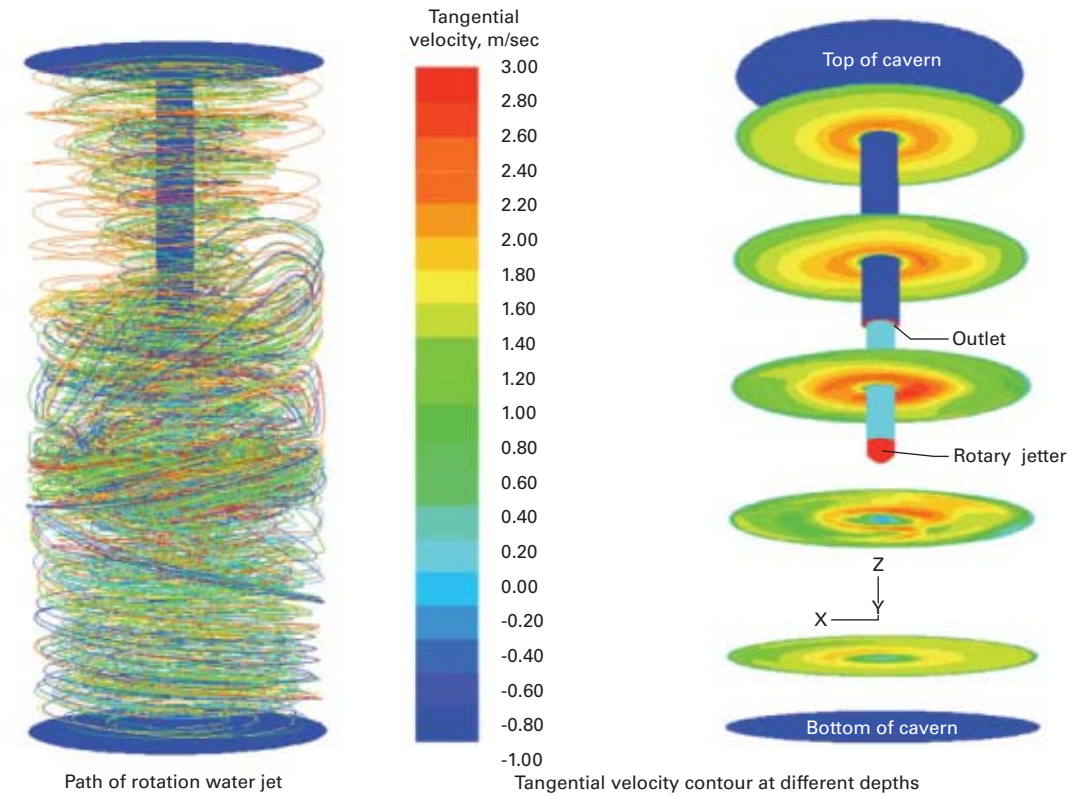
## HELICAL FLOW; 50 CU M/HR, 60 RPM

Fig. 5




Path of rotation water jet

Tangential velocity contour at different depths

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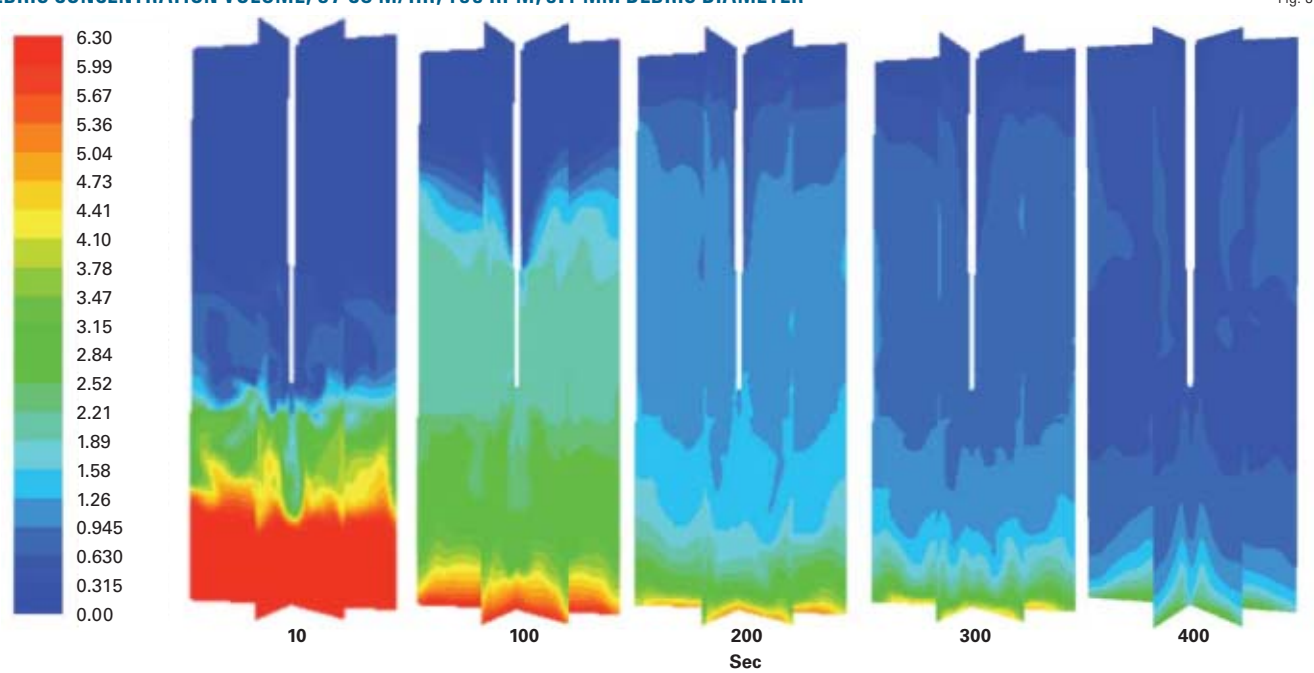
## DEBRIS CONCENTRATION VOLUME; 57 CU M/HR, 100 RPM, 0.1 MM DEBRIS DIAMETER

Fig. 6



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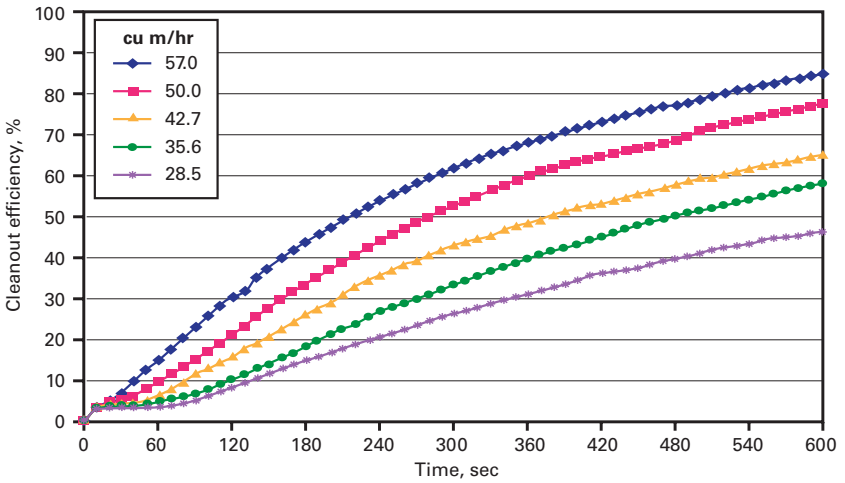
CLEANOUT EFFICIENCY; 0.1 MM DEBRIS DIAMETER, 60 RPM

Fig. 7

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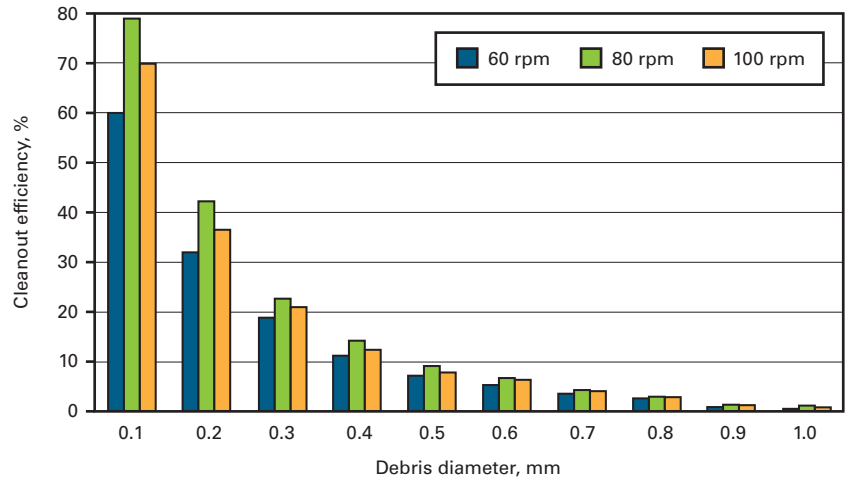
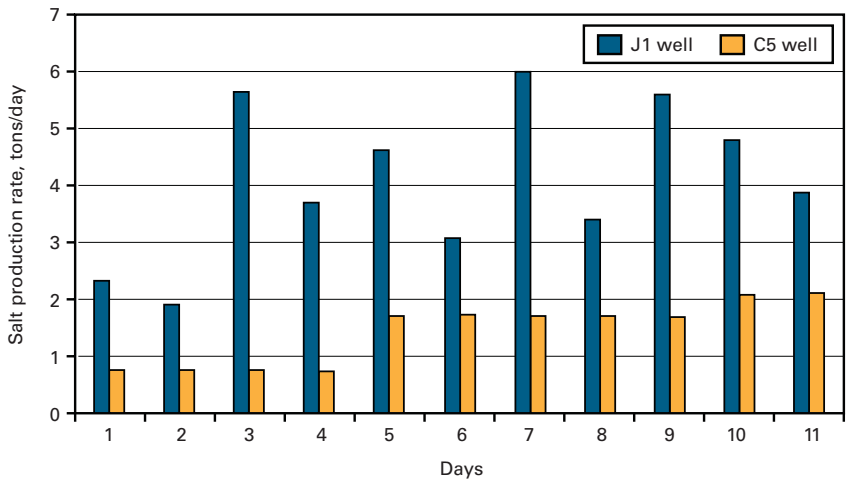
## CLEANOUT EFFICIENCY, 42.7 CU M/HR FOR 10 MIN

Fig. 8



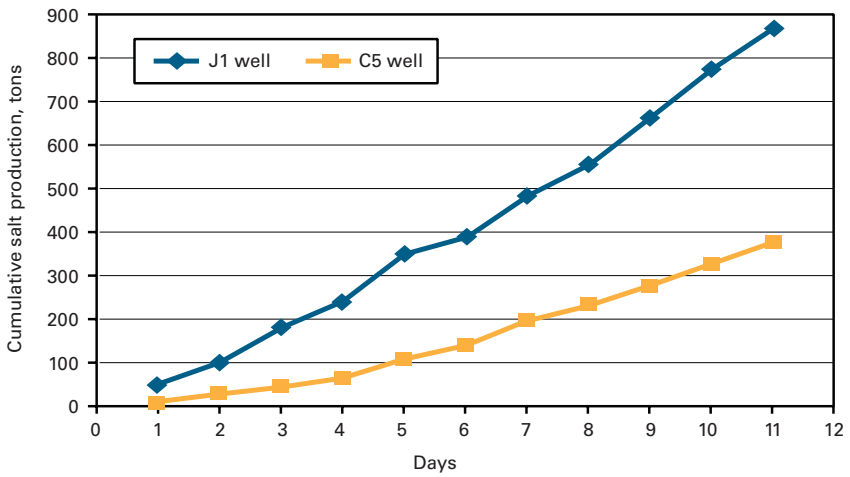

## SALT PRODUCTION RATES

Fig. 9




## SALT PRODUCTION

Fig. 10

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## Imports of crude and products

| | Districts 1-4 | | District 5 | | Total US | | |
|---|---|---|---|---|---|---|---|
| | 11-27 2008 | 11-20 2008 | 11-27 2008 | 11-20 2008 | 11-27 2008 | 11-20 2008 | *11-28 2007 |
| | 1,000 b/d | | | | | | |
| Total motor gasoline | 1,035 | 873 | 65 | 55 | 1,100 | 928 | 884 |
| Mo. gas. blending comp. | 831 | 736 | 65 | 52 | 896 | 788 | 784 |
| Distillate | 136 | 234 | 0 | 0 | 136 | 234 | 116 |
| Residual | 359 | 279 | 18 | 50 | 377 | 329 | 576 |
| Jet fuel-kerosine | 54 | 37 | 9 | 65 | 63 | 102 | 45 |
| Propane-propylene | 239 | 153 | 8 | 7 | 247 | 160 | 185 |
| Other | 358 | 213 | (22) | 16 | 336 | 229 | 523 |
| **Total products** | **3,012** | **2,525** | **143** | **245** | **3,155** | **2,770** | **3,113** |
| **Total crude** | **7,534** | **7,928** | **867** | **1,022** | **8,401** | **8,950** | **9,504** |
| **Total imports** | **10,546** | **10,453** | **1,010** | **1,267** | **11,556** | **11,720** | **12,617** |

*Revised.
Source: US Energy Information Administration
Data available in OGJ Online Research Center.

## Purvin & Gertz LNG netbacks—Dec. 4, 2008

| Receiving terminal | Liquefaction plant | | | | | |
|---|---|---|---|---|---|---|
| | Algeria | Malaysia | Nigeria | Austr. NW Shelf | Qatar | Trinidad |
| | $/MMbtu | | | | | |
| Barcelona | 6.71 | 4.52 | 5.87 | 4.41 | 5.11 | 5.79 |
| Everett | 4.12 | 2.01 | 3.75 | 2.09 | 2.56 | 4.41 |
| Isle of Grain | 3.71 | 1.61 | 3.08 | 1.51 | 2.16 | 3.11 |
| Lake Charles | 2.23 | 0.34 | 2.01 | 0.50 | 0.73 | 2.85 |
| Sodegaura | 5.18 | 7.55 | 5.43 | 7.24 | 6.42 | 4.48 |
| Zeebrugge | 6.19 | 3.98 | 5.54 | 3.87 | 4.60 | 5.60 |

Definitions, see OGJ Apr. 9, 2007, p. 57.
Source: Purvin & Gertz Inc.
Data available in OGJ Online Research Center.

## Crude and product stocks

| District | Crude oil | Motor gasoline | | Jet fuel, kerosine | Fuel oils | | Propane-propylene |
|---|---|---|---|---|---|---|---|
| | | Total | Blending comp.[1] | | Distillate | Residual | |
| | 1,000 bbl | | | | | | |
| PADD 1 | 12,890 | 56,184 | 39,645 | 11,748 | 75,385 | 14,182 | 4,691 |
| PADD 2 | 84,680 | 50,262 | 24,461 | 7,472 | 29,028 | 1,131 | 24,325 |
| PADD 3 | 171,465 | 71,298 | 41,186 | 13,023 | 46,298 | 19,139 | 30,693 |
| PADD 4 | 16,017 | 6,613 | 2,341 | 596 | 3,300 | 187 | [1]2,272 |
| PADD 5 | 54,847 | 29,724 | 25,710 | 8,981 | 11,687 | 3,417 | — |
| **Nov. 27, 2009** | **339,899** | **214,081** | **133,343** | **41,820** | **165,698** | **38,056** | **61,981** |
| **Nov. 20 2009** | **337,808** | **210,085** | **130,319** | **42,388** | **166,868** | **36,929** | **63,647** |
| **Nov. 28, 2009[2]** | **320,372** | **198,942** | **105,529** | **38,567** | **124,973** | **37,156** | **60,329** |

[1]Includes PADD 5. [2]Revised.
Source: US Energy Information Administration
Data available in OGJ Online Research Center.

## Refinery report—Nov. 27, 2009

| District | Refinery operations | | Refinery output | | | | |
|---|---|---|---|---|---|---|---|
| | Gross inputs | Crude oil inputs | Total motor gasoline | Jet fuel, kerosine | Fuel oils: Distillate | Fuel oils: Residual | Propane-propylene |
| | 1,000 b/d | | | | | | |
| PADD 1 | 1,063 | 1,064 | 2,306 | 52 | 313 | 101 | 44 |
| PADD 2 | 3,064 | 3,053 | 2,271 | 214 | 907 | 46 | 225 |
| PADD 3 | 7,015 | 6,858 | 2,651 | 621 | 2,088 | 427 | 671 |
| PADD 4 | 539 | 542 | 302 | 36 | 175 | 6 | [1] 56 |
| PADD 5 | 2,396 | 2,327 | 1,495 | 411 | 421 | 145 | -- |
| **Nov. 27, 2009** | **14,077** | **13,844** | **9,025** | **1,334** | **3,904** | **725** | **996** |
| **Nov. 20, 2009** | **14,182** | **13,971** | **9,184** | **1,316** | **3,979** | **655** | **1,032** |
| **Nov. 28, 2008[2]** | **14,852** | **14,580** | **8,716** | **1,411** | **4,314** | **552** | **1,046** |
| | **17,672 Operable capacity** | | **79.7% utilization rate** | | | | |

[1]Includes PADD 5. [2]Revised.
Source: US Energy Information Administration
Data available in OGJ Online Research Center.

Additional analysis of market trends is available through **OGJ Online**, *Oil & Gas Journal's* electronic information source, at http://www.ogjonline.com.

OIL&GAS JOURNAL online research center

## OGJ crack spread

| | *12-4-09 | *12-5-09 | Change $/bbl | Change, % |
|---|---|---|---|---|
| **SPOT PRICES** | | | | |
| Product value | 83.86 | 50.82 | 33.04 | 65.0 |
| Brent crude | 77.62 | 42.99 | 34.63 | 80.6 |
| Crack spread | 6.23 | 7.83 | -1.59 | -20.3 |
| **FUTURES MARKET PRICES** | | | | |
| **One month** | | | | |
| Product value | 84.72 | 51.54 | 33.18 | 64.4 |
| Light sweet crude | 76.84 | 45.50 | 31.34 | 68.9 |
| Crack spread | 7.89 | 6.04 | 1.84 | 30.5 |
| **Six month** | | | | |
| Product value | 91.31 | 60.61 | 30.70 | 50.6 |
| Light sweet crude | 82.25 | 52.61 | 29.64 | 56.3 |
| Crack spread | 9.07 | 8.01 | 1.06 | 13.2 |

*Average for week ending.
Source: Oil & Gas Journal
Data available in OGJ Online Research Center.

# Statistics

## OGJ GASOLINE PRICES

| | Price ex tax 12-2-09 | Pump price* 12-2-09 | Pump price 12-3-08 |
|---|---|---|---|
| | ¢/gal | | |
| (Approx. prices for self-service unleaded gasoline) | | | |
| Atlanta | 225.6 | 257.0 | 192.9 |
| Baltimore | 217.6 | 259.5 | 183.6 |
| Boston | 217.6 | 259.5 | 188.1 |
| Buffalo | 207.8 | 271.0 | 187.8 |
| Miami | 223.1 | 276.0 | 191.9 |
| Newark | 218.6 | 251.5 | 192.8 |
| New York | 207.8 | 271.0 | 198.2 |
| Norfolk | 211.8 | 249.5 | 187.8 |
| Philadelphia | 216.3 | 267.0 | 197.2 |
| Pittsburgh | 214.8 | 265.5 | 202.1 |
| Wash., DC | 227.1 | 269.0 | 207.0 |
| PAD I avg | 217.1 | 263.3 | 193.6 |
| Chicago | 231.2 | 286.3 | 189.6 |
| Cleveland | 226.9 | 273.3 | 172.8 |
| Des Moines | 208.9 | 249.3 | 173.3 |
| Detroit | 224.7 | 276.3 | 182.8 |
| Indianapolis | 221.2 | 271.3 | 179.6 |
| Kansas City | 200.6 | 236.3 | 165.9 |
| Louisville | 219.4 | 260.3 | 174.9 |
| Memphis | 201.5 | 241.3 | 170.7 |
| Milwaukee | 215.0 | 266.3 | 174.9 |
| Minn.-St. Paul | 214.7 | 260.3 | 173.6 |
| Oklahoma City | 187.9 | 223.3 | 166.5 |
| Omaha | 200.6 | 246.3 | 167.8 |
| St. Louis | 199.6 | 235.3 | 177.9 |
| Tulsa | 184.9 | 220.3 | 168.4 |
| Wichita | 194.9 | 238.3 | 172.0 |
| PAD II avg | 208.8 | 252.3 | 174.1 |
| Albuquerque | 212.3 | 249.5 | 186.0 |
| Birmingham | 214.8 | 254.1 | 177.9 |
| Dallas-Fort Worth | 208.1 | 246.5 | 171.9 |
| Houston | 210.1 | 248.5 | 167.7 |
| Little Rock | 203.3 | 243.5 | 181.7 |
| New Orleans | 216.2 | 254.6 | 186.1 |
| San Antonio | 212.7 | 251.1 | 186.9 |
| PAD III avg | 211.1 | 249.7 | 179.7 |
| Cheyenne | 221.9 | 254.3 | 172.5 |
| Denver | 219.0 | 259.4 | 191.1 |
| Salt Lake City | 211.0 | 253.9 | 176.5 |
| PAD IV avg | 217.3 | 255.9 | 180.0 |
| Los Angeles | 232.1 | 297.9 | 209.8 |
| Phoenix | 220.5 | 257.9 | 199.8 |
| Portland | 237.5 | 280.9 | 214.8 |
| San Diego | 233.1 | 298.9 | 219.8 |
| San Francisco | 239.1 | 304.9 | 215.1 |
| Seattle | 239.0 | 294.9 | 209.8 |
| PAD V avg | 233.6 | 289.2 | 211.5 |
| **Week's avg.** | **215.5** | **260.3** | **185.9** |
| **Nov. avg.** | **218.8** | **263.6** | **215.5** |
| **Oct. avg.** | **208.4** | **253.6** | **317.6** |
| **2009 to date** | **185.3** | **230.8** | — |
| **2008 to date** | **291.6** | **335.8** | — |

*Includes state and federal motor fuel taxes and state sales tax. Local governments may impose additional taxes.
Source: Oil & Gas Journal.
Data available in OGJ Online Research Center.

## REFINED PRODUCT PRICES

| | 11-27-09 ¢/gal | | 11-27-09 ¢/gal |
|---|---|---|---|
| **Spot market product prices** | | | |
| Motor gasoline (Conventional-regular) | | Heating oil No. 2 | |
| New York Harbor | 194.35 | New York Harbor | 193.45 |
| Gulf Coast | 189.65 | Gulf Coast | 194.54 |
| Los Angeles | 190.65 | Gas oil | |
| Amsterdam-Rotterdam-Antwerp (ARA) | 194.75 | ARA | 193.93 |
| Singapore | 192.55 | Singapore | 197.38 |
| Motor gasoline (Reformulated-regular) | | Residual fuel oil | |
| New York Harbor | 191.85 | New York Harbor | 176.67 |
| Gulf Coast | 186.60 | Gulf Coast | 174.12 |
| Los Angeles | 196.15 | Los Angeles | 190.34 |
| | | ARA | 175.67 |
| | | Singapore | 176.91 |

Source: DOE Weekly Petroleum Status Report.
Data available in OGJ Online Research Center.

## BAKER HUGHES RIG COUNT

| | 12-4-09 | 12-5-08 |
|---|---|---|
| Alabama | 4 | 4 |
| Alaska | 7 | 12 |
| Arkansas | 40 | 54 |
| California | 25 | 40 |
| Land | 24 | 40 |
| Offshore | 1 | 0 |
| Colorado | 37 | 113 |
| Florida | 0 | 1 |
| Illinois | 0 | 1 |
| Indiana | 3 | 2 |
| Kansas | 19 | 11 |
| Kentucky | 12 | 10 |
| Louisiana | 176 | 185 |
| N. Land | 116 | 95 |
| S. Inland waters | 15 | 18 |
| S. Land | 11 | 21 |
| Offshore | 34 | 51 |
| Maryland | 0 | 0 |
| Michigan | 0 | 0 |
| Mississippi | 6 | 19 |
| Montana | 8 | 8 |
| Nebraska | 0 | 0 |
| New Mexico | 47 | 71 |
| New York | 3 | 3 |
| North Dakota | 60 | 86 |
| Ohio | 8 | 12 |
| Oklahoma | 87 | 175 |
| Pennsylvania | 61 | 27 |
| South Dakota | 0 | 1 |
| Texas | 451 | 852 |
| Offshore | 2 | 7 |
| Inland waters | 0 | 0 |
| Dist. 1 | 24 | 24 |
| Dist. 2 | 13 | 33 |
| Dist. 3 | 34 | 63 |
| Dist. 4 | 30 | 87 |
| Dist. 5 | 67 | 157 |
| Dist. 6 | 51 | 126 |
| Dist. 7B | 14 | 27 |
| Dist. 7C | 38 | 61 |
| Dist. 8 | 84 | 118 |
| Dist. 8A | 19 | 30 |
| Dist. 9 | 34 | 49 |
| Dist. 10 | 41 | 70 |
| Utah | 17 | 39 |
| West Virginia | 22 | 30 |
| Wyoming | 40 | 79 |
| Others—HI-1; NV-2; OR-1; TN-1; VA-3 | 8 | 17 |
| **Total US** | **1,141** | **1,852** |
| **Total Canada** | **364** | **404** |
| **Grand total** | **1,505** | **2,256** |
| US Oil rigs | 383 | 413 |
| US Gas rigs | 748 | 1,428 |
| Total US offshore | 37 | 63 |
| **Total US cum. avg. YTD** | **1,082** | **1,886** |

Rotary rigs from spudding in to total depth.
Definitions, see OGJ Sept. 18, 2006, p. 42.

Source: Baker Hughes Inc.
Data available in OGJ Online Research Center.

## SMITH RIG COUNT

| Proposed depth, ft | Rig count | 12-4-09 Percent footage* | Rig count | 12-5-08 Percent footage* |
|---|---|---|---|---|
| 0-2,500 | 83 | 1.2 | 80 | 1.2 |
| 2,501-5,000 | 67 | 73.1 | 63 | 69.8 |
| 5,001-7,500 | 128 | 28.1 | 124 | 25.0 |
| 7,501-10,000 | 229 | 8.2 | 226 | 6.6 |
| 10,001-12,500 | 251 | 12.3 | 241 | 12.8 |
| 12,501-15,000 | 160 | 2.5 | 159 | 3.1 |
| 15,001-17,500 | 152 | — | 152 | — |
| 17,501-20,000 | 62 | — | 59 | — |
| 20,001-over | 32 | — | 30 | — |
| **Total** | **1,164** | **12.0** | **1,134** | **11.1** |
| INLAND | 17 | | 29 | |
| LAND | 1,112 | | 1,853 | |
| OFFSHORE | 35 | | 52 | |

*Rigs employed under footage contracts.
Definitions, see OGJ Sept. 18, 2006, p. 42.

Source: Smith International Inc.
Data available in OGJ Online Research Center.

## OGJ PRODUCTION REPORT

| | [1]12-4-09 | [2]12-5-08 |
|---|---|---|
| | 1,000 b/d | |
| (Crude oil and lease condensate) | | |
| Alabama | 20 | 22 |
| Alaska | 705 | 722 |
| California | 640 | 650 |
| Colorado | 70 | 67 |
| Florida | 7 | 5 |
| Illinois | 26 | 25 |
| Kansas | 111 | 110 |
| Louisiana | 1,428 | 1,091 |
| Michigan | 17 | 16 |
| Mississippi | 64 | 61 |
| Montana | 87 | 85 |
| New Mexico | 169 | 163 |
| North Dakota | 220 | 213 |
| Oklahoma | 185 | 182 |
| Texas | 1,400 | 1,340 |
| Utah | 67 | 64 |
| Wyoming | 152 | 146 |
| All others | 67 | 72 |
| **Total** | **5,435** | **5,034** |

[1]OGJ estimate. [2]Revised.
Source: Oil & Gas Journal.
Data available in OGJ Online Research Center.

## US CRUDE PRICES

| | 12-4-09 $/bbl* |
|---|---|
| Alaska-North Slope 27° | 64.51 |
| South Louisiana Sweet | 75.75 |
| California-Midway Sunset 13° | 66.50 |
| Lost Hills 30° | 74.60 |
| Wyoming Sweet | 65.97 |
| East Texas Sweet | 71.50 |
| West Texas Sour 34° | 67.00 |
| West Texas Intermediate | 72.00 |
| Oklahoma Sweet | 72.00 |
| Texas Upper Gulf Coast | 65.00 |
| Michigan Sour | 64.00 |
| Kansas Common | 71.50 |
| North Dakota Sweet | 63.75 |

*Current major refiner's posted prices except North Slope lags 2 months. 40° gravity crude unless differing gravity is shown.
Source: Oil & Gas Journal.
Data available in OGJ Online Research Center.

## WORLD CRUDE PRICES

| $/bbl[1] | 11-27-09 |
|---|---|
| United Kingdom-Brent 38° | 76.47 |
| Russia-Urals 32° | 75.67 |
| Saudi Light 34° | 75.91 |
| Dubai Fateh 32° | 77.54 |
| Algeria Saharan 44° | 77.17 |
| Nigeria-Bonny Light 37° | 78.33 |
| Indonesia-Minas 34° | 80.35 |
| Venezuela-Tia Juana Light 31° | 74.78 |
| Mexico-Isthmus 33° | 74.67 |
| OPEC basket | 76.75 |
| Total OPEC[2] | 76.43 |
| Total non-OPEC[2] | 74.87 |
| Total world[2] | 75.75 |
| US imports[3] | 73.34 |

[1]Estimated contract prices. [2]Average price (FOB) weighted by estimated export volume. [3]Average price (FOB) weighted by estimated import volume.
Source: DOE Weekly Petroleum Status Report.
Data available in OGJ Online Research Center.

## US NATURAL GAS STORAGE[1]

| | 11-27-09 | 11-20-09 | 11-27-08 | Change, % |
|---|---|---|---|---|
| | bcf | | | |
| Producing region | 1,219 | 1,211 | 963 | 26.6 |
| Consuming region east | 2,092 | 2,099 | 1,938 | 7.9 |
| Consuming region west | 526 | 525 | 466 | 12.9 |
| **Total US** | **3,837** | **3,835** | **3,367** | **14.0** |
| | **Sept. 09** | **Sept. 08** | **Change, %** | |
| **Total US[2]** | **3,643** | **3,163** | **15.2** | |

[1]Working gas. [2]At end of period.
Source: Energy Information Administration
Data available in OGJ Online Research Center.

# WORLDWIDE CRUDE OIL AND GAS PRODUCTION

| | Sept. 2009 | Aug. 2009 | 9 month average production 2009 | 9 month average production 2008 | Change vs. previous year Volume | Change vs. previous year % | Sept. 2009 | Aug. 2009 | Cum. 2009 |
|---|---|---|---|---|---|---|---|---|---|
| | Crude, 1,000 b/d | | | | | | Gas, bcf | | |
| Argentina | 610 | 529 | 606 | 604 | 1 | 0.2 | 120.0 | 119.7 | 1,076.90 |
| Bolivia | 40 | 40 | 40 | 40 | — | –0.6 | 40.0 | 40.0 | 365.00 |
| Brazil | 1,993 | 1,960 | 1,936 | 1,807 | 129 | 7.2 | 31.0 | 29.0 | 263.00 |
| Canada | 2,485 | 2,524 | 2,544 | 2,578 | –34 | –1.3 | 389.2 | 401.6 | 3,834.30 |
| Colombia | 680 | 669 | 653 | 575 | 78 | 13.5 | 35.0 | 30.0 | 275.00 |
| Ecuador | 460 | 460 | 474 | 500 | –26 | –5.1 | 2.0 | 2.0 | 18.00 |
| Mexico | 2,599 | 2,542 | 2,608 | 2,822 | –214 | –7.6 | 210.7 | 220.8 | 1,921.38 |
| Peru | 112 | 109 | 105 | 73 | 32 | 43.3 | 11.3 | 11.4 | 90.00 |
| Trinidad | 101 | 106 | 108 | 113 | –5 | –4.4 | 107.3 | 120.8 | 1,022.33 |
| United States | 5,327 | 5,286 | 5,250 | 4,961 | 289 | 5.8 | 1,776.0 | 1,871.0 | 16,471.00 |
| Venezuela[1] | 2,240 | 2,210 | 2,150 | 2,359 | –209 | –8.9 | 70.0 | 72.0 | 620.00 |
| Other Latin America | 83 | 84 | 83 | 83 | — | — | 5.4 | 5.5 | 49.16 |
| **Western Hemisphere** | **16,730** | **16,519** | **16,557** | **16,516** | **41** | **0.2** | **2,798.0** | **2,923.7** | **26,006.07** |
| Austria | 18 | 19 | 19 | 17 | 2 | 8.9 | 3.8 | 4.4 | 40.06 |
| Denmark | 256 | 271 | 267 | 289 | –21 | –7.4 | 23.9 | 22.0 | 200.69 |
| France | 18 | 18 | 18 | 20 | –2 | –8.3 | 2.4 | 2.5 | 23.90 |
| Germany | 54 | 54 | 56 | 61 | –4 | –7.1 | 39.8 | 39.2 | 382.63 |
| Italy | 78 | 80 | 81 | 101 | –20 | –19.7 | 18.0 | 21.0 | 196.50 |
| Netherlands | 24 | 23 | 26 | 35 | –9 | –25.9 | 150.0 | 130.0 | 1,840.00 |
| Norway | 1,923 | 1,970 | 2,061 | 2,151 | –90 | –4.2 | 255.1 | 262.6 | 2,701.84 |
| Turkey | 47 | 48 | 45 | 41 | 4 | 9.7 | — | — | — |
| United Kingdom | 1,126 | 984 | 1,339 | 1,409 | –70 | –5.0 | 137.4 | 121.4 | 1,647.94 |
| Other Western Europe | 4 | 5 | 3 | 4 | –1 | –14.0 | 0.1 | 0.2 | 8.85 |
| **Western Europe** | **3,547** | **3,472** | **3,916** | **4,127** | **–212** | **–5.1** | **630.5** | **603.3** | **7,042.41** |
| Azerbaijan | 1,030 | 1,050 | 1,033 | 933 | 101 | 10.8 | 45.0 | 40.0 | 330.00 |
| Croatia | 13 | 14 | 14 | 15 | –1 | –7.4 | 4.3 | 4.6 | 45.55 |
| Hungary | 14 | 14 | 14 | 15 | –1 | –4.6 | 6.7 | 7.2 | 63.66 |
| Kazakhstan | 1,400 | 1,350 | 1,287 | 1,189 | 98 | 8.2 | 100.0 | 100.0 | 900.00 |
| Romania | 90 | 90 | 90 | 93 | –3 | –3.6 | 18.0 | 19.0 | 166.00 |
| Russia | 10,100 | 9,940 | 9,856 | 9,747 | 109 | 1.1 | 1,400.0 | 1,350.0 | 13,150.00 |
| Other FSU | 400 | 450 | 444 | 400 | 44 | 11.1 | 350.0 | 300.0 | 2,900.00 |
| Other Eastern Europe | 42 | 40 | 43 | 48 | –5 | –10.3 | 17.6 | 17.8 | 169.64 |
| **Eastern Europe and FSU** | **13,090** | **12,947** | **12,781** | **12,440** | **342** | **2.7** | **1,941.7** | **1,838.6** | **17,724.85** |
| Algeria[1] | 1,220 | 1,220 | 1,239 | 1,379 | –140 | –10.2 | 240.0 | 245.0 | 2,215.00 |
| Angola[1] | 1,870 | 1,800 | 1,760 | 1,905 | –145 | –7.6 | 6.0 | 6.0 | 46.00 |
| Cameroon | 72 | 72 | 74 | 85 | –12 | –13.7 | — | — | — |
| Congo (former Zaire) | 25 | 25 | 25 | 25 | — | — | — | — | — |
| Congo (Brazzaville) | 240 | 240 | 240 | 240 | — | — | — | — | — |
| Egypt | 630 | 630 | 642 | 672 | –30 | –4.5 | 115.0 | 120.0 | 1,090.00 |
| Equatorial Guinea | 320 | 320 | 320 | 320 | — | — | 0.1 | 0.1 | 0.54 |
| Gabon | 240 | 240 | 226 | 233 | –8 | –3.3 | 0.3 | 0.3 | 2.73 |
| Libya[1] | 1,550 | 1,550 | 1,554 | 1,726 | –171 | –9.9 | 37.0 | 38.0 | 334.00 |
| Nigeria[1] | 1,850 | 1,740 | 1,779 | 1,953 | –174 | –8.9 | 90.0 | 90.0 | 781.00 |
| Sudan | 500 | 500 | 500 | 487 | 13 | 2.7 | — | — | — |
| Tunisia | 78 | 78 | 83 | 84 | –2 | –1.9 | 8.4 | 8.6 | 73.29 |
| Other Africa | 221 | 221 | 221 | 221 | — | — | 8.6 | 9.1 | 79.00 |
| **Africa** | **8,816** | **8,637** | **8,663** | **9,332** | **–669** | **–7.2** | **505.4** | **517.1** | **4,621.56** |
| Bahrain | 30 | 30 | 29 | 29 | — | 0.1 | 28.0 | 30.0 | 234.82 |
| Iran[1] | 3,700 | 3,800 | 3,748 | 3,932 | –184 | –4.7 | 275.0 | 290.0 | 2,570.00 |
| Iraq[1] | 2,500 | 2,480 | 2,391 | 2,442 | –51 | –2.1 | 22.0 | 22.0 | 181.00 |
| Kuwait[1,2] | 2,230 | 2,240 | 2,273 | 2,609 | –336 | –12.9 | 34.0 | 36.0 | 326.00 |
| Oman | 790 | 850 | 803 | 720 | 83 | 11.6 | 50.0 | 55.0 | 501.00 |
| Qatar[1] | 760 | 760 | 764 | 857 | –92 | –10.8 | 215.0 | 220.0 | 1,987.00 |
| Saudi Arabia[1,2] | 8,190 | 8,200 | 8,176 | 9,292 | –1,117 | –12.0 | 215.0 | 220.0 | 1,933.00 |
| Syria | 360 | 360 | 372 | 387 | –14 | –3.7 | 17.0 | 18.0 | 157.00 |
| United Arab Emirates[1] | 2,270 | 2,270 | 2,269 | 2,638 | –369 | –14.0 | 130.0 | 135.0 | 1,175.00 |
| Yemen | 260 | 260 | 273 | 309 | –36 | –11.7 | — | — | — |
| Other Middle East | — | — | — | — | — | –5.5 | 10.1 | 12.0 | 83.22 |
| **Middle East** | **21,090** | **21,250** | **21,099** | **23,215** | **–2,116** | **–9.1** | **996.1** | **1,038.0** | **9,148.05** |
| Australia | 454 | 481 | 466 | 448 | 18 | 4.1 | 109.2 | 138.1 | 1,110.08 |
| Brunei | 145 | 142 | 148 | 160 | –11 | –7.0 | 35.0 | 35.0 | 311.36 |
| China | 3,837 | 3,854 | 3,751 | 3,799 | –48 | –1.3 | 243.1 | 251.2 | 2,207.09 |
| India | 665 | 666 | 658 | 673 | –14 | –2.1 | 116.4 | 120.3 | 906.25 |
| Indonesia[1] | 860 | 850 | 856 | 861 | –5 | –0.6 | 195.0 | 200.0 | 1,795.00 |
| Japan | 14 | 14 | 16 | 17 | –1 | –7.1 | 8.8 | 9.1 | 90.03 |
| Malaysia | 730 | 720 | 733 | 762 | –29 | –3.8 | 135.0 | 140.0 | 1,235.00 |
| New Zealand | 61 | 60 | 49 | 58 | –9 | –15.2 | 13.0 | 13.0 | 110.90 |
| Pakistan | 63 | 63 | 64 | 67 | –3 | –4.6 | 118.0 | 124.6 | 1,100.12 |
| Papua New Guinea | 35 | 35 | 37 | 42 | –4 | –10.7 | 0.9 | 1.0 | 8.60 |
| Thailand | 221 | 239 | 240 | 228 | 12 | 5.4 | 37.0 | 37.0 | 306.34 |
| Vietnam | 325 | 310 | 294 | 278 | 16 | 5.7 | 20.0 | 20.0 | 180.00 |
| Other Asia–Pacific | 96 | 48 | 49 | 42 | 6 | 14.7 | 91.5 | 94.5 | 836.50 |
| **Asia–Pacific** | **7,505** | **7,482** | **7,361** | **7,433** | **–73** | **–1.0** | **1,122.9** | **1,183.8** | **10,197.27** |
| **TOTAL WORLD** | **70,778** | **70,307** | **70,376** | **73,062** | **–2,686** | **–3.7** | **7,994.5** | **8,104.6** | **74,740.21** |
| OPEC | 28,840 | 28,730 | 28,578 | 32,452 | –3,875 | –11.9 | 1,336.0 | 1,376.0 | 14,286.00 |
| North Sea | 3,326 | 3,245 | 3,688 | 3,867 | –180 | –4.7 | 461.3 | 444.9 | 5,100.87 |

[1]OPEC member. [2]Kuwait and Saudi Arabia production each include half of Neutral Zone. Totals may not add due to rounding.
Source: Oil & Gas Journal. Data available in OGJ Online Research Center.

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| Liquid Terminals | 8,457 | 2,983 | 28,325 | 22,693 | 19,142 | 8,933 | 2,637 |
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| Electric Utility | 27,586 | 13,117 | 81,906 | 62,193 | 49,642 | 25,432 | 9,160 |
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| International E&P | 10,796 | 4,647 | 25,495 | 16,684 | 16,869 | 7,459 | 2,818 |
| United States & Canada E&P | 38,595 | 23,500 | 81,713 | 51,098 | 54,145 | 27,242 | 6,758 |
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## Responses reveal more than e-mails in 'Climategate'

*In the controversy known as "Climategate," responses by chagrined climate activists reveal even more than embarrassing e-mails.*

*"There is no alternative theory that the minority is proposing," declared Rep. Ed Markey (D-Mass.), at a hearing of the House Select Committee on Energy Independence and Global Warming. "The deniers have decided to use a small number*

The Editor's Perspective

*by Bob Tippee, Editor*

*of e-mails as a way to cast doubt."*

*False. There is indeed an alternative theory. It is that natural forces contribute far more than human emissions of greenhouse gases do to global warming.*

*But that theory, like any refinement that doesn't support imposition of martial law on energy markets, has been systematically derided as unserious science.*

*Now, however, e-mails leaked or stolen from the University of East Anglia in the UK show scientists important to the urgent-response agenda distorting data and gaming academic journals to marginalize opponents.*

*The e-mails uphold suspicions that the campaign to engineer climate feeds more off propaganda than science, that it depends on the immunization of a questionable theory against question.*

*With shameful help from the popular media, activists have successfully depicted questioners as corrupt loons. After East Anglia, the ploy won't work.*

*So overextended politicians like Markey resort to falsehood as their exertions to suppress debate become desperate.*

*Equally appalling is the statement of Nicholas Stern, a professor at the London School of Economics and Political Science who, while working in the UK government, led a 2006 study that said benefits of strong warming precautions outweigh costs.*

*"People have the right to speak up," Stern said after the East Anglia dust-up, according to the Telegraph newspaper of London. "But if they are muddled and confused then they do not have the right to be described as anything other than muddled and confused on the basis of the arguments they set out and what is wrong with them."*

*Stern's argument by characterization is typical, and his assertion is false. The case against precipitous response to warming is as clear and unconfused as any on the other side.*

*That it hasn't received a fair hearing is the biggest part of the scandal.*

*(Online Dec. 4, 2009; author's e-mail: bobt@ogjonline.com)*

Market Journal

*by Sam Fletcher, Senior Writer*

## Gas oil market out to sea

Barring an extremely cold winter and stronger-than-expected economic recovery, the phenomenon of gas oil inventories stored at sea in transport vessels will continue next year, said analysts at Deutsche Bank AG.

Best estimates indicate nearly 100 million bbl of gas oil are now in floating storage around the globe, much of it off Europe. However, weather forecasters expect above-normal temperatures in northern Europe through much of December.

"While floating gas oil has been symptomatic of the global downturn, it's now become a fundamental overhang on the market as industry participants struggle to make sense of this phenomenon in oil supply-demand balances," Deutsche Bank analysts reported Dec. 4. "This will continue to weigh on the gas oil complex and margins next year at a time when refiners, particularly in the US and Europe, are struggling to cope with the rapid increase in new refinery capacity in China and India."

Because there is no official reporting system, it's difficult to say how much gas oil is stored in vessels at sea. The International Energy Agency estimated 60 million bbl of oil and 80 million bbl of distillates were in floating storage at the end of October. The Organization of Petroleum Exporting Countries put the numbers at 40 million bbl of crude and 90 million bbl of distillates. ICAP Shipping International Ltd. projected 90 million bbl of distillates in floating storage by the end of November. That is expected to grow to 97 million bbl in December—a fivefold increase in floating distillate stocks within 9 months. Olivier Jakob at Petromatrix, Zug, Switzerland, earlier said, "If the current rate of increase in distillate floating stocks continues, we would have at the end of March 2010 more distillate stocks on water than we had in March 2008 in the total onshore US (OGJ Online, Nov. 30, 2009)."

Based on their reading of industry surveys and media reports, Deutsche Bank analysts estimate global gas oil inventories on the water has grown to 100 million bbl, up from estimates of 24 million bbl as of last April.

### Converging factors

The highly unusual buildup of seaborne inventories of gas oil (diesel and heating oil) began early this year as the result of a combination of factors. Deutsche Bank analysts said, "Shipping rates were crushed due to the recessionary impact on oil flows and that coincided with the completion of a significant number of new vessels that were added to the global fleet. The recessionary impact on diesel demand was global, but more pronounced in the US and Europe, and also resulted in a persistent and deep contango...as wide as $3.15/bbl in June this year, on a monthly average basis." With onshore inventories already near capacity, it became economic for the first time to store gas oil on vessels for an extended period.

Some portion of floating gas oil, albeit not the dominant share, is stored on very large crude carriers, each of which can hold up to 2 million bbl, Deutsche Bank reported. "The use of VLCCs to transport clean products such as gasoline or gas oil is hardly if ever done given contamination issues. Transporting gas oil in a vessel that had been carrying crude oil likely will result in gas oil product that is off-specification and unmarketable," analysts said. "The VLCCs being used to store gas oil are brand new to the fleet; hence their holds have not been coated with crude so they can carry clean products without resulting in off-spec product."

Meanwhile, refinery runs have remained low so far this year, down 540,000 b/d on average from a year ago. Deutsche Bank analysts reported gas oil production is sharply lower at an average 300,000 b/d. They estimated 4% of US refinery capacity was idled this year because of unprofitable margins. In Europe, at least 8% of capacity was idled "either permanently or for an extended period of time due to poor margins," they said.

Bank analysts foresee three possible scenarios for heating oil:

- An average winter would result in lowering heating oil demand by 8.6% for October 2009 through March 2010. "This is exaggerated due to a very cold winter...that boosted demand by 14% October 2008 to March 2009," they said.
- If this winter proves to be the coldest in 5 years, analysts said, heating oil demand would climb 120,000 b/d above the baseline but still down 3.7% for the year.
- The warmest winter in 5 years would slash demand 170,000 b/d below the baseline, down 15% on a year-on-year basis.

(Online Dec. 7, 2009; author's e-mail: samf@ogjonline.com)

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# Plugging and Abandoning Hurricane-Damaged Wells

## Vented Inflatable System Eliminates Gas Bubbles, Enables Successful Cement Plugs

Many hurricane-damaged wells in the Gulf of Mexico have to be permanently plugged and abandoned. Operators have discovered that many of these wells are bubbling, which creates challenges when placing cement barriers in the wells.

### Gas Bubbles Passing Through Microannuli

Inflatable packers such as Baker Oil Tools' Production Injection Packer (PIP), deployed as a pressure sealing base on which a cement plug is placed, is often a suitable fix for this problem. However, gas bubbles sometimes find a way around the PIP and work their way through the cement, creating microannuli even after the cement sets up. These bubbles travel through microscopic pits or fissures in the old casing. This was the challenge an operator faced in a High Island well with 26-in., 125 lbf casing.

### Vented PIP System

To solve this problem reliably and economically, Baker Hughes developed the Vented PIP System, a new method of stopping the flow of bubbles. The system consists of a PIP (with a ball on seat below it), a length of vent tubing above it, and a mechanical disconnect on top of that.

### Bubbles in Well Stopped Immediately

Once the system was set at depth, bubbles in the well stopped immediately. Simultaneously, a substantial flow of gas was observed through the work string at surface. The operator then ran a grout string (small work string) beside the primary work string to a depth just above the inflated element. Cement was then pumped through the grout string on top of the PIP. A cement volume was pumped that equaled about 50 ft in the annulus between the 26-in. casing ID and the OD of the 2 7/8-in. tubing. While this cement cured, the vent tubing and work string were kept open to vent the gas to surface. This prevented gas buildup below the PIP and kept bubbles from affecting the cement job. Once the cement had completely cured, a cast iron bridge plug was run through the primary work string and set in the vent tubing above the PIP. This resulted in a permanently plugged well.

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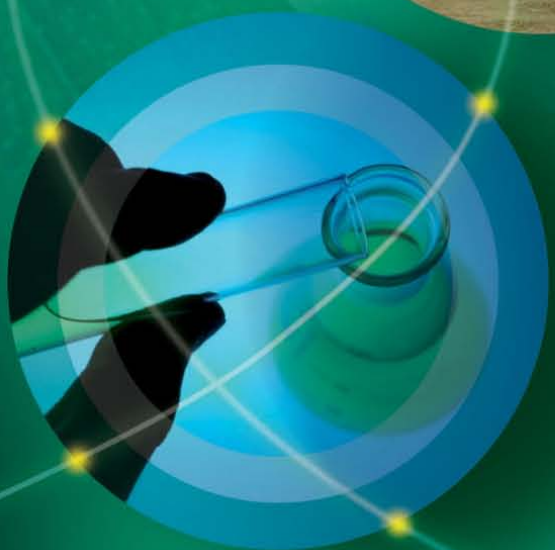
# SPAIN, A GLOBAL LEADER IN RENEWABLE ENERGY



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# A New Power

## In the last decade, Spain has emerged as a world leader in renewable energy production and technology

Spain's abundant natural resources have long been celebrated – it is the sunniest and also one of the windiest countries in Europe. But it is only in recent years that the technology and the regulatory framework have been developed which have meant that these resources can now be harnessed.

The results have been dramatic. For the last five years, Spain has been installing on average 2000MW per year of wind capacity alone. Wind energy has now overtaken hydroelectricity as a contributor to Spain's total energy, with installed wind power capacity rising to 16,740MW at the end of 2008, from 2,198MW in 2000, and is heading for a target of 20,155MW in 2010.

**We are investing in a technology which is still expensive….so that our companies can be well positioned and competitive in the international market."**

**Pedro Marín Uribe, Spain's Secretary of State for Energy**

That makes Spain the fourth largest producer of wind power worldwide, and the second largest in Europe behind Germany: one blustery morning in March 2009, wind power generated over 11,000MW, covering nearly 30% of Spain's total electricity demand.

Meanwhile, in the solar power sector, in 2008 Spain was responsible for 45% of all new photovoltaic capacity installed worldwide, and the country now has more PV power installed per capita than any other. In terms of biofuels, the government has set a target of biofuels supplying 3.4% and 5.83% of transport fuels in 2009 and 2010 respectively, up from 0.32% in 2003.

Under Spain's Renewable Energy Plan for 2005-2010, some 23.6 billion euros are being invested in the sector, creating 95,000 net jobs and avoiding 77 million tons of CO2 emissions, with 30.3% of electricity consumption set to come from renewables in 2010. Spain has also signed up to the European Union's binding 20% target for the share of renewables in total energy consumption and a 10% share in transport fuels in 2020.

"The Renewable Energy Plan set a photovoltaic target of under 400MW for 2010, and we are already at around 3,500MW, while we had a 500MW target for solar thermal, and with the requests that we are seeing we could easily reach 1,000MW," says Spain's Secretary of State for Energy, Pedro Marín Uribe. "We are clearly going to meet our targets for 2010 in terms of electricity generation, and we will probably beat them easily."

Motivated partly by concerns over security of supply, with over 80% of Spain's energy needs coming from imports, successive Spanish governments have provided generous premiums for renewable energy generators, in the shape of attractive feed-in tariffs and subsidies for investments in the sector.

Antoni Castells, the Minister for Finance, Economy and Energy in Catalonia explains that "our energy policy is very clear and we know that we are facing a fundamentel change of model, due to three main reasons: firstly, because of the need to reduce production of CO2 emissions, secondly, because of the dependence on external energy, and thirdly the dependence on and the price of hydrocarbons. These three factors are driving a change of model, which we feel is absolutely necessary."

The Spanish example has been one of the great success stories in global renewable energy policy. "Spain has become one of the world leaders in renewable energy development, particularly in wind and solar power energy," the International Energy Agency said in its review of Spain in September 2009. "The national government and the autonomous regions see renewable energy as bringing environmental and energy security benefits, as well as enhancing local employment and economic development."

And not only has this policy resulted in a securer, more diversified and cleaner energy mix, but it has also spawned a group of world leading companies in the sector, including Iberdrola, the largest renewable energy producer in the world, Acciona and turbine manufacturer Gamesa, and solar and biofuels leader Abengoa. According to Spanish wind power association, AEE, Spanish companies have now installed over 8000MW of wind power worldwide.

"I think that first of all the fact that in Spain regulations have been stable, and returns have been predictable and sufficient, has led to the right conditions needed for the sector to develop," says Xabier Viteri, CEO of Iberdrola Renovables, the renewable energy arm of Iberdrola. "Spain also has the renewable resources available, and it has invested in improving infrastructure, particularly in electricity, which has enabled the sector to grow. Companies such as ours are now a source of job creation and of innovation, and I think that Spain can be a good example for other countries."

"Other countries have chosen different policies, such as waiting for renewable energy to be cheaper, before incorporating it in their energy system," Pedro Marín Uribe explains. "But we have chosen to invest in technology. I think that this is one of the only times in the history of Spain that we have made such a strong commitment to a new technology. We are investing in a technology which is still expensive….so that our companies can be well positioned and competitive in the international market."

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Spanish energy policy has also transformed the landscapes of historic regions such as Andalusia and Castilla La Mancha, bringing state of the art technology and innovation across the country, and has turned cities such as Madrid and Barcelona into world leading centers for research and development into renewable energy.

"In terms of megawattage in renewable energy, Catalonia has practically 18 times the MW that Provence has installed, and Provence is the most advanced region in France in photovoltaic energy and renewable energy," says Josep Huguet i Biosca, the Regional Minister for Innovation, Universities and Companies of Catalonia. "In the Mediterranean region, Spain is by far the most advanced country in the region, whether it be in photovoltaic, or thermo solar or wind."

The rapid growth of the market in Spain, and the accompanying increase in industry know-how, is also attracting significant levels of foreign investment from the likes of Vestas of Denmark and Alstom of France, which in 2007 acquired wind turbine manufacturer Ecotècnia for 350 million euros, and which now runs its wind turbine business out of Barcelona.

"During 2008, we installed an additional 1.8GW in Spain, which represents about 2-3% of the global market, a huge proportion of the global market," says Alfonso Faubel, vice president of Alstom Wind. "I think this has been possible due to the Spanish government's policy, as they really have a clear renewable energy policy that is good for climate change and good for creating jobs."

Juan Araluce, President of rival Vestas Mediterranean, agrees with that assessment. "The level of activity in Spain has been such that we have four manufacturing facilities in Spain, he says. "Our annual exports from Spain now represent two billion euros, and we have 1800 workers in Spain in factories, maintenance, etc. We hope that this figure reaches 2500 people by 2012."

The renewable energy sector has not been immune to the global economic slowdown, in Spain or elsewhere. Spain has been hit particularly hard by the downturn, and by the collapse of its own housing and construction boom, with the European Commission expecting a 3.7% fall in GDP in 2009.

With the government's fiscal position under pressure, its assistance to the renewable energy sector has come under scrutiny from some quarters, and it has slashed subsidies to the solar sector and is tightening up its requirements for support to wind power. But Enrique Díaz-Tejeiro, chairman of Solaria, the only solar power company that is listed on the Spanish stock exchange, believes that cutting subsidies will serve as a strong incentive to the sector. "A subsidy is always a kind of smoke. It is an interesting way to help but only for short-term purposes…we believe that subsidies should always have been less than what they have been up till now, and it's up to the companies, by setting a good example in reducing costs, to see that the photovoltaic industry becomes competitive."

And Rafael Gimeno, who runs the Madrid Renewable Energy cluster, is also upbeat on the future of the industry in Spain: "of course the current economic climate will lead to slower growth rates than in the past, but a lot of countries, and Spain is one of them, have made a major political commitment to the development of green energy. I think that once we get through this crisis, we will again see job creation in the sector, and even at a higher rate than before."

With continued political and regulatory support, and with nearly unrivalled experience and know-how across the country, Spain seems set to remain in the vanguard of the global renewable energy industry.

# Windmill Giants

## It is Don Quixote's worst nightmare. Companies such as Iberdrola, Acciona and Gamesa have become major players in the global wind energy market.

Regulatory support for wind energy from the government, including favorable feed-in tariffs, and private sector investment have not only helped to diversify and secure Spain's energy supply, but have also turned Spanish wind farm developers and technology suppliers into global leaders in the sector.

"The support of the Spanish government has not only helped our company within Spanish boundaries, but it has helped Spain expand its business to new markets," says Alfonso Faubel, Vice President of turbine manufacturer Alstom Wind.

And with growth in Spain now under pressure from controversial new legislation, the local wind power sector is increasingly focused on overseas opportunities, particularly in the United States.

"The US is the leading country in terms of installed wind power capacity, but as a percentage of electricity generation it is still very limited compared to some European countries, such as Spain," says Xabier Viteri, chief executive officer of Iberdrola Renovables, "there is still a lot of room to grow."

"The US government has also demonstrated a clear will to commit to our sector, and we think that we are now in the position where we can invest more than 6 billion dollars in the US from 2009-2012."

### Privileged position

The Spanish wind power sector has become a major contributor to national exports and GDP: according to a Deloitte study for Spanish wind power association AEE, the Spanish sector is now composed of over 700 companies, which are active in 27 countries, employing 37,730 people and contributing 0.35% of GDP. In 2008, the sector supplied 11.5% of Spain's electricity needs, after adding 10,532MW of capacity in the last five years.

Spanish companies are making major inroads into the US. Data from the US International Trade Commission show that Spain was the second largest provider of wind-powered generated sets to the US in 2007 and 2008, with overall exports rising from just $45.8 million in 2003 to $467.7 million in 2008.

"The effort that we have made as a country in wind energy means that we are now in a privileged position," says José Javier Armendáriz, director general of CENER, the National Renewable Energy Centre, "we are in a leading position in Europe and in the US."

And with President Obama saying that he aims to follow the Spanish lead in renewable energy, the presence of Spanish companies in the US wind power sector now seems set to rise.

"It is clearly great news that President Obama has cited Spain as an example in renewable energy," says Spain's Secretary of State for Energy Pedro Marín Uribe. "I believe that our companies can play a major role in this area in the US. So far the experience of our companies in the US has been very positive…our companies and our government are interested in working with the US on making the development of renewable energy in the world a reality."

In the global equipment market, Spain's Gamesa is the world's number three producer of wind turbines, with 10.8% market share in 2008, behind Vestas and GE, while Acciona had 4.1% of the market.

"On a global scale, Spain represents 12% of all Vestas sales, which is extremely high for one country and for a country that is so relatively small," says Juan Araluce, President of Vestas Mediterranean.

Meanwhile, according to BTM Consult's World Market Update 2008, in terms of installed wind power capacity Iberdrola Renovables is the world number one, with 8,960MW installed, while Acciona is at number four with 4,566MW and Endesa is eighth with 1,925MW.

"This is probably the first time that Spain is leading the world," says Juan Verde, President of the Climate Project Spain, the local branch of the organisation founded by Al Gore which aims to raise public awareness about climate

change. "Spain missed the boat in the industrial revolution and then in the IT revolution of the 1980s and 1990s, but now the companies will be able to grow internationally and lead the transformation in the US."

In Spain itself, Iberdrola Renovables has 27% of installed wind power capacity, ahead of Acciona, with 16%, Endesa with 10%, and Eufer, a joint venture between Union Fenosa and Italy's Enel, on 4%.

In the Spanish wind turbine market, Gamesa has a 49% share, ahead of Vestas on 14.7%, while number three player Alstom Wind is now expanding rapidly in the Spanish market, with share of 13.7% in 2008.

And in addition to the economic impact of wind energy, the environmental consequences of the sector's expansion have also been significant: in 2008, wind power in Spain avoided 18 million tons of CO2 emissions.

"Spain shows that it can be done," says The Climate Project Spain's President Juan Verde. "It has gone from a country with basically no investments in the renewable energy sector eight years ago to leading the world in solar and wind energy."

"If it's been done here it can be done elsewhere – creating green jobs and economic opportunities. It could be a way out of the crisis here in Spain and a way for Spain to stop being so dependent on the tourism and construction sectors and be more sustainable in the long term. Spain really has a story to tell other nations."

*Regions like Navarra are investing heavily in renewables.*

## New legislation

However, new legislation published in May 2009 has served to dampen some enthusiasm in the sector.

In an attempt to reduce subsidy payments at a time of rising budget deficits, and to increase its control over the energy sector, the government has established a pre-registration condition for wind power developers, imposing a series of financial and operating requirements on the developers before they can benefit from the special tariffs for wind power. These pre-qualification requirements, which include making a financial deposit, have added a new layer of red tape and have led to a slowdown in the market.

"Recently the legislation has become a lot tougher for our customers", says Alstom Wind's Mr. Faubel. "We are seeing that this is creating a bit of stagnation in the market…It is similar to what has happened in the USA, where until the stimulus package was published there was a total stagnation in the industry. The Royal Decree has created a similar situation, but of course not as serious."

*Acciona's wind turbine generator plant in Iowa, US.*

Other companies in the turbine sector also voice their concern: "while we have this uncertainty, the banks are not providing finance, and the whole industry is in a stagnant state," says Juan Araluce of Vestas.

"For the wind industry in Spain, it is fundamental to have a stable legislation which supports the development of this sector," says Javier Perea, Managing Director, Commercial Construction and Services at Gamesa.

Regional politicians are also opposed to the law. "We need the legislative crisis to be sorted out at national level," says Salvador Marín, the Minister for Universities, Enterprise and Research in the region of Murcia. "For an investment to be made, it needs to have clarity, stability, and security."

"We don't like the new legislation because it was approved by the cabinet without consulting either the sector or the regions," says Antonio Cejalvo Lapeña of Aven, the Valencia Energy Agency. "The law doesn't endanger investments that have already been made, as they have guaranteed sale prices for electricity, but it could threaten future developments."

The result of this slowdown in the domestic market is that Spanish wind power companies are now focused on overseas markets.

"Because of the situation that has been created in Spain, all of the companies in the sector are looking to the exterior," says José Maria González Pérez, chairman of renewable energy business association APPA. "Clearly the US is one of our leading markets, as well as countries in the European Union and also developing countries. If major obstacles are imposed in Spain, we will have to install renewables in other countries."

## Electric car scheme

But it is not attractive tariffs and regulations alone that have supported the expansion of the Spanish wind power sector. Wind power, because of its intermittent and unpredictable nature, poses major challenges to the transmission system, and Spain has made a concerted effort in adapting its transmission infrastructure to the rise in wind power capacity.

"Spain is exemplary in developing wind power," the International Energy Agency said in its September 2009 survey. "It has succeeded in developing a well integrated system to balance the inevitable variations in wind power generation…a key tool is the world class Renewable Energy Control System of the Transmission System Operator."

And in an innovative effort to better integrate wind energy into the Spanish electricity system, the government is implementing an ambitious scheme for developing infrastructure for electric cars, Project Movele, which could also cut carbon emissions and reduce Spain's dependence on fossil fuels on the roads.

Electric cars are a particularly useful complement to wind energy as they help address the main technological problems of wind power – that the electricity produced cannot easily be stored and can overload the grid at times of high wind and low electricity demand, usually during the night. When there is an excess of wind power, turbines have to be disconnected so as not to overload the system, and with Spanish installed wind power approaching 20,000MW, times when the electricity system cannot absorb all the wind power could become more frequent.

The Spanish government believes that this excess electricity could be used in the night to recharge electric cars, which would store the electricity from wind power in their batteries, ensuring that electricity from wind power can be used even on calm days.

In the longer term, electric cars in turn could even supply electricity back to the grid, in a so-called Vehicle-to-Grid or V2G system.

"The prospect of using wind energy to charge electric vehicles is a good example of a holistic approach much needed in energy policy, and should be encouraged," the IEA says.

**"One year ago the electric vehicle plan sounded utopian, and in just one year most regional governments have decided to commit to electric vehicles."**

**Pedro Marín Uribe, Spain's Secretary of State for Energy**

The government is spending 8 million euros in a pilot scheme in the cities of Madrid, Barcelona and Seville, which will involve 2,000 subsidized vehicles and 500 recharge points, and has set a target of one million hybrid and electric cars by 2014.

"A year ago when this Ministry launched its Energy Efficiency Saving Plan, the electric vehicle plan sounded utopian," says Pedro Marín Uribe, "and in just one year most regional governments have decided to commit to electric vehicles, while the car companies are working intensely on these sorts of vehicles and are all calling us to have their prototypes and new vehicles included in our catalogue of electric vehicles….nobody wants to miss out on this."

As other nations play catch up with Spain in their wind energy sector, often turning to Spanish developers and equipment suppliers, Spain itself is now moving ahead to lock in the social and economic benefits of wind power.

*Klondike, in Portland, Oregon (US), is the biggest windfarm owned by Iberdrola Renovables with 400MW.*

## Setting the Pace

It was back in 2001, long before the start of the global renewable energy boom, that Ignacio Galán, then the newly appointed chief executive officer of Iberdrola and now also the company's chairman, decided that renewable energy would be one of the cornerstones of Iberdrola's new growth strategy.

The implementation of that strategy has seen Iberdrola, from its base in Bilbao in the Basque Country, grow into what is now the world's largest producer of renewable energy, after investing an unrivalled 10 billion euros in installing almost 10,500MW of renewable energy capacity. For 2010, the company has a target of raising that level to about 12,500MW of installed capacity.

It is its continuing ability to seize on market opportunities early in the day that time and time again has seen Iberdrola consolidate its leadership of the global renewable energy sector. Recent proof of this has been its acquisition of Scottish Power in 2007 and of Energy East in the US in 2008, just as the UK and the US were embarking on a major drive in renewable energy.

Again with perfect timing, in December 2007 Iberdrola sold a 20% stake of its renewable energy subsidiary Iberdrola Renovables, in a $6 billion initial public offering. The company is now the tenth largest in the blue chip IBEX-35 index and has a presence in 23 countries.

And although Iberdrola Renovables is mainly a wind energy company, as that is the most competitive type of renewable energy, it is committed to innovation, research and development, and it is establishing leading positions in other types of renewable energy, such as solar thermal and biomass.

Iberdrola Renovables is now stepping up its program of internationalisation. "We will continue to improve the geographical diversification of our assets," Galán said at a recent results presentation for Iberdrola Renovables.

**"We will continue to improve the geographical diversification of our assets."**

**Ignacio Galán, Chairman of Iberdrola Renovables**

At the end of the third quarter of 2009, the installed capacity of the company outside Spain represented 50.3% of the total - the first time that the company's international business contributed more than the domestic business.

The company has a particular focus on opportunities in the US. "At the end of 2010, 35% of our assets will be in the US," Galán said at the results presentation. Iberdrola Renovables has said that it will invest around 6 billion dollars in the US to the end of 2012, supported by the country's ambitious targets for increasing installed capacity in renewable energy and by the favourable regulatory framework that has been implemented since the arrival of Barack Obama at the White House.

However, countries such as Spain and the United Kingdom will remain priority markets for Iberdrola Renovables, and it will continue to explore future opportunities such as Eastern Europe and some countries in Latin America, such as Mexico and Brazil.

And it is not just Iberdrola shareholders who have benefited from the spectacular growth of the company over the last nine years. Iberdrola has long been characterised by its commitment to society and the environment: in Spain, Iberdrola Renovables has inaugurated energy information centres in four landmark wind farms, and it has opened the first renewable energy education centre in Scotland. In 2008 alone, Iberdrola Renovables created 10,000 jobs worldwide, while its own workforce rose by 38% to total nearly 2,000 employees.

Above all, Iberdrola's installed capacity of renewable energy generates enough electricity for 21 million people, avoiding the emission of 8.5 million tonnes of $CO_2$ per year, while also helping the countries where it is present to reduce their levels of energy dependence and to increase their energy security. Few companies in the renewable energy sector can have contributed as much as Iberdrola Renovables to the challenge of sustainable development.

*Whitelee, the biggest windfarm in Europe.*


*The design and manufacturing in Spain of wind turbines is the core business of Alstom Wind.*

## Powering Up

When global power giant Alstom decided to expand its position in the wind energy sector in 2007, it turned to Spain, acquiring local turbine manufacturer Ecotècnia, which has delivered it with a significant share of the booming Spanish market and which has completed Alstom's global renewable energy portfolio.

The success of the acquisition has been largely based on the integration of Ecotecnia's wind power know-how with Alstom's global structure and customer base, its project management capabilities, and the financial support and balance sheet strength of a blue chip multinational that dates back to 1928.

**"One of Alstom's main advantages over competitors is that it can integrate all of its technologies and offer that complete portfolio to its customer base."**

**Alfonso Faubel, Vice President of Alstom Wind.**

The company has market share of around 14% of installed wind energy capacity in Spain. About 50% of sales are now generated outside Spain, and the company aims to increase this proportion by leveraging the Alstom footprint, in particular in the US and China.

Alfonso Faubel, vice president of Alstom Wind, says that in addition to offering a seamless A-Z service in wind, one of Alstom's main advantages over competitors who focus just on wind turbine manufacturing is that it can integrate all of its technologies and offer that complete portfolio to its customer base. Alstom offers a complete portfolio of energy technologies, ranging from fossil fuels, to nuclear to hydroelectricity.

And on the technological side, the Pure Torque™ technology of Alstom Wind is proving to be a real differentiator in the turbine market: this unique rotor concept protects the gearbox by transferring all unwanted wind turbulence directly to the tower, while only the torque is transferred to the gearbox.

Alstom is the only company in the market which can offer customers such a reliable turbine. "Our competitors consider a gearbox to be a consumable," Faubel explains. "We think that should not be the case….and there is sufficient evidence over several years of statistical data that would suggest that our failure rate is just fraction of our competitors'."

The design and manufacturing in Spain of state of the art wind turbines is the core business of Alstom Wind. In October 2009, Alstom opened the first wind farm to include the world's largest production line onshore turbine, the 3MW Ecotècnia 100 (see box page 3).

The Ecotècnia 100 platform joins the highly successful Ecotècnia 80 platform; there are over 700MW of these turbines, ranging from 1.67MW to 2.0MW, in operation worldwide.

And the R&D road does not end there. Alstom is also working on the ECO110, which will have a rotor size of 110 meters. While the Eco 100 is suitable for sites with an average wind speed of up to 8.5m/s, the Eco 11O is designed for sites with a lower average annual wind speed of up to 7.5m/s.

"As we see the evolution of the European market, we can see the importance of the larger wind turbines." Faubel explains. "The bigger they are the fewer turbines you need." The ECO110 prototype will be up and running in Spain by the end of 2009.

All of these new platforms incorporate the Pure Torque™ technology, for increased turbine reliability. "It really is a different concept that our competitors do not have," says Félix Urrea Pérez, VP Operations Europe. "For us it was not difficult to grow from the 1.67MW model to 3MW, because we were just scaling up the technology."

In the US, Alstom is working on introducing its ECO80 class II and ECO86 class III models in 2010, while the ECO 100 is being prepared for US entry by 2011. Faubel says that the company is currently preparing the ECO100 to the US specifications, "for customers who want larger turbines to maximize yield on their terrain."

The high reliability and high energy yield of the new platforms will be critical as Alstom turns its attentions to the markets of China and the US. "Because of the availability of sites with less wind, you need to have a product that will function in these conditions, so the Eco 100 and Eco 110 products are ideal," Faubel explains.

"We are opening up a manufacturing base in the USA and we are taking our entry into the US market very seriously. The footprint of Alstom today in the US is 12,000 people. and we haven't even fully started with wind, so we will add to this number."

*Gas turbine. Working on compressor inlet.*

*Italpu hydroelectric dam, Brazil.*

# Regions Transformed

## The Spanish industrial landscape is being transformed, as regional governments look to leverage their natural resources and diversify their economies

The town of Puertollano lies at the edge of the central Spanish plain of Castilla La Mancha, right before the frontier with the rolling mountains of Andalusia, and was once nothing but a sleepy agricultural village, until the discovery of extensive coal deposits and the construction of a petrochemical complex and oil refinery turned it into the industrial heart of the region.

Now Puertollano is undergoing its second transformation, with the coal mines replaced by factories producing solar panels and wafers, by wind farms and by research centers into hydrogen cells and concentrated solar power. Iberdrola Renovables opened its first solar thermal plant here in May 2009, while leading solar player Solaria produces solar modules from its factory in Puertollano.

Puertollano is just the clearest example of how the Spanish industrial landscape is being transformed by renewable energy, as across Spain, regional governments aggressively support the sector, in order to bring added value and high technology to their economies, and to diversify away from construction and tourism.

That Puertollano is located in Castilla La Mancha is no coincidence. It was in the blazing heat and windswept plains of this region that Don Quixote set off on his quests, and today the region has more wind power than any other in Spain, with over 3,500MW installed, and over 800MW of photovoltaic solar.

The wind and the sun by themselves have not engineered this boom in renewable energy: in 1998, Paula Fernández Pareja, Minister for Industry, Energy and Environment in the region, explains, the regional government made a strategic commitment to renewable energy, and since then has prioritized renewable energy investments in local legislation and in infrastructure development.

Other Spanish regions have been slower to support the development of wind energy. The IEA noted in its September 2009 survey of Spain that one specific area for improvement is the large discrepancy in permitting and siting procedures that exist in different autonomous regions.

*Acciona's control center for renewable facilities.*

*Iberdrola Renovables' first solar thermal plant.*

This issue is being addressed by Catalonia, which plans to increase wind power capacity from 86.7MW in 2003 to 3500MW in 2015, according to Mr Antoni Castells, Minister of Finance, Economy and Energy. In order to meet this target, Castells explains, the regional government is streamlining the permit process: "we have just signed a new decree for wind power in Catalonia, whereby we can approve wind power plants in a much easier and more efficient manner."

Within Catalonia's Energy Plan 2006-2015, Catalonia has set ambitious targets to quadruple consumption of renewable energy, reaching a total of 11% of total energy consumption by 2015. As Castells explains "we are certainly on the right path towards achieving our objectives for 2015. When we came into government in 2003, in wind power alone we were producing only 86.7MW and today we are producing 496MW. The economic recession is opening up a whole new industrial sector of renewable energy, we believe that it will be one of the fastest growing sectors of the future and in Catalonia we are prepared for this."

Meanwhile, the capital Madrid, which has less wind and solar resources than other regions in Spain, is investing heavily in turning the city into a hub for research and development and high added value activities. Here, IMADE, the Madrid Institute for Development, is playing a leading role; it has already invested 1.1 billion euros since 2007 in setting up clusters and science parks with over three hundred companies and institutions, as part of its goal of seeing Madrid take its place among the top ten advanced regions in the world in 2020.

IMADE has also established a specific cluster for the sustainability and renewable energy sector in Madrid which is focused on encouraging innovation, sharing know-how and accessing financing.

Madrid is the main motor of the Spanish economy, and will have a major part to play in its recovery and diversification. The efforts being made by IMADE and the clusters look like ensuring that Madrid will consolidate its role in the forefront of the renewable energy sector that will be at the heart of Spain's new economic model.

The greater economic strength of Madrid, and the strong commitment of the regional government to the development of renewable energy, means that the impact of the crisis in Madrid is much less than in the rest of the country, says the cluster's manager, Rafael Gimeno.

**"The recession has affected neither our priorities nor the pace of our work."**

Aurelio García de Sola, Manager of IMADE

"The recession has affected neither our priorities nor the pace of our work, we are continuing to work on the projects", agrees Aurelio García de Sola, the manager of IMADE. "The renewable energy sector has all the ingredients to help to renew the Spanish economy".

■ Foreign Direct Investment

Madrid, 21th October 2009

SPAIN RANKS SIXTH AMONG OECD COUNTRIES MOST INVESTED BY FOREIGN COMPANIES

Spain moves up two places on the Foreign Investment league table and is now the sixth biggest receiver of foreign

Advances in telecoms technology, and the de

# The Madrid Region concentrated 82% of foreign direct investment into Spain during 2008

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*Solar plant developed by Madrilean company Affirma.*

## Madrid on the Map

In recent years, the region of Madrid has emerged as the epicentre of Spain's dynamic renewable energy sector, and it is also now increasingly recognized as a leading location for research and development and as a strategic hub for European and global business operations.

Nearly 500 companies, employing over 44,000 people, are active in the sector in Madrid, over half of whom have set up in the region since 2000. In addition to the leading Spanish wind energy company, Iberdrola, standout names in the solar PV sector who have based themselves in Madrid include Suntech, Yingli, Sunpower, Conergy and First Solar, while solar thermal companies Viessmann, Wagner Solar, Tisun and Bosch and Schüco are all present in the region. In the concentrating solar power sub sector, Madrid is home to players such as Solfocus, Infinia Solar and Solar Reserve.

In addition, oil major Repsol has based its R&D centre for biofuels in Madrid, and Abengoa, Alfa Laval, and Gea Group all have significant biofuel operations in the region, while in the bioenergy area German multinational RWE Innogy is developing projects across Spain from its bases in Madrid.

PromoMadrid, the regional government company that promotes Madrid as a base for foreign investment and supports the internationalisation of local companies, calculates that the renewable industry contributes over EUR10 billion to the GDP of the Madrid region. That figure should rise to over EUR20 billion in 2020, PromoMadrid estimates. It is not only the abundant natural resources and attractive regulatory framework in Spain, or the know-how that has come with the growth of the market, that are drawing these companies to Madrid. Costs are also more competitive than in other major European regions, while companies have easy access to a highly qualified, multilingual labour pool, with over 64,000 engineering students at the fourteen universities in Madrid.


*Mr Jesús Sainz, President of PromoMadrid.*


*The new Terminal 4 at Madrid-Barajas airport.*


*Madrid, an innovation hub.*

Crucially, the regional government has also made a concerted effort to support the development of the sector and attract foreign investment. The government has established the Madrid Cluster for Renewable Energy and Sustainability, which serves as a platform for the sector that brings together companies, universities, R&D centres and the regional administration, so that they can pool interests and develop specific projects together.

Madrid is particularly focused on moving up the value chain in the renewable industry, by encouraging more investment in research and development in the region. To this end, in 2008 the regional government created the Madrid Institute for Advance Research in Energy (IMDEA Energy), which is designed to concentrate resources and talent in the field of innovation in renewable energy.

Other leading R&D centres in the Madrid region include the prestigious Solar Energy Institute (IES), the National Centre for Research in Technology, Environment and Energy (CIEMAT), and the National Institute for Energy Saving and Diversification.

All of these initiatives are serving to consolidate and increase the level of research and development in the sector, and to raise the Madrid region's stock of renewable energy know-how, which will help Madrid to attract more companies to invest in the sector.

And in addition, because of its strategic geographical location right at the heart of the Iberian Peninsula, coupled with state of the art logistics, such as brand new Terminal 4 at Barajas airport, Madrid has also become a popular and attractive base for companies looking well beyond just the Spanish market.

Danish wind turbine giant Vestas now runs all of its sales business for the Mediterranean, Middle East, North Africa, Latin America and the Caribbean from its headquarters in Madrid.

And as well as its geographic position, which makes it a natural gateway to the wider European and Mediterranean markets, Madrid also has unrivalled economic and cultural connections to Latin America.

"We want also to continue being the epicentre in Europe of the relationship with Latin America, which will allow renewable energy companies based in the Madrid Region to develop their activities in this new and very promising market, particularly when they near grid parity" said Mr Jesús Sainz, President of PromoMadrid.

# Ambitious biofuels targets

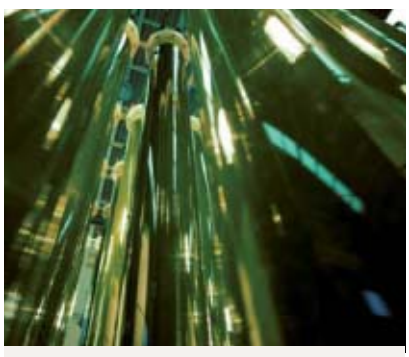
## New government targets should help the biofuels market

Following the establishment of mandatory biofuels quotas by the Spanish government, there has been a surge in biofuels consumption in Spain, providing the sector with a platform to be at the forefront of the development of second generation biofuels.

According to renewable energy association APPA, Spain is the number three European producer of bioethanol and the number seven producer of biodiesel. In July 2007, the government set mandatory quotas for biofuel content in gasoline of 3.4% in 2009 and 5.83% in 2010, and according to APPA in the first half of 2009 the market share of biofuels had risen to 2.97%, up from a level of just 1.15% in 2007.

In order to help Spain meet its targets, in September 2009 Abengoa Bioenergy acquired the 50% it did not already own in the 200 million liter ethanol plant Biocarburantes de Castilla y León, in Salamanca. Abengoa Bioenergy now has combined installed capacity of over 1.5 billion liters of bioethanol in the US, Europe and Brazil and is the leading producer in Europe.

The Salamanca acquisition also positions Abengoa for the imminent revolution in biofuels, with the commercialisation of second generation biofuels, based not on food crops such as sugar cane and oil seeds but on non-food materials, which are more competitive with fossil fuels in terms of cost and which have a higher energy yield. The Salamanca complex includes a five million liter pilot plant for producing bioethanol from cereal straw.



*Bioreactors. BFS biopetroleum production plant.*

"We want experience in all kinds of raw materials, so that we can develop them with new technologies and make more sustainable products," says Abengoa Bioenergy CEO Javier Salgado.

"Only with new technologies can we hope in the long term to have biofuel products that are economically competitive," says Luis Cabra, a corporate director at Spanish oil giant Repsol, which each year blends 300,000 tons of bioethanol derivative ETBE with gasoline in its refineries. "We need a new generation of biofuels derived from other raw materials."

And it is a Spanish company, Bio Fuel Systems, established in 2006, that says it has developed one of the keys to the biofuels of the future and which has caught the attention of the world's energy industry. The company says it can make fuel out of microalgae in the sea and has established the world's first production plant of what it calls biopetroleum, in Alicante. BFS says its system will be able to produce 1,400 times more energy than any other source of biodiesel.

"We are in negotiations with a major oil company," says Bio Fuel Systems chairman Bernard A.J Stroïazzo-Mougin, "and we have signed an agreement with them on technology development…in two or three years we plan to invest two billion euros in constructing twenty plants. Our target is to achieve in a ten year period a 10% share of the world market."

# A Case of Sunstroke

## A government crackdown on subsidies has halted the solar boom. The sector is now looking ahead to achieving grid parity by cutting costs.

The Spanish solar power sector has enjoyed an unprecedented expansion in recent years, culminating in 2008, when solar photovoltaic capacity increased by over 400% to 3,120MW, the highest amount per capita in the world, and the 50MW Andasol 1 plant, the largest solar thermal power plant in Europe, was inaugurated in Andalusia.

This surge in photovoltaic and solar thermal capacity, triggered largely by the very attractive feed-in tariffs set by the government, has seen Spain consolidate its position as a global leader in the solar power industry: 7% of the world's production of photovoltaic generators are now manufactured here.

*Acciona 46MW PV plant in Portugal.*

### Leading the Way

Solaria Energia y Medio Ambiente is one of the most prominent solar photovoltaic companies in Spain, and is well known for its focus on reducing generation costs in this sector. The relatively young company has enjoyed rapid growth in Spain, and is now increasing its international profile, in Europe and beyond.

Solaria manufactures crystalline silicon cells and modules, develops turnkey projects, and also operates solar photovoltaic plants which are owned by Solaria and by third parties.

The company has a strong commitment to developing solutions that will reduce the final production cost of solar photovoltaic electricity, and it is targeting grid parity for southern and central Europe, and competitive system costs in other regions.

Outside of Spain, Solaria already has trade offices in Germany, Italy and France, and it has a global pipeline of projects that include activities in every major region.

In Spain, Solaria is focusing on implementing a strategy of vertical integration, and it has recently added state-of-the-art cell manufacturing lines to its existing module manufacturing sites. This addition to its business has provided Solaria with a competitive advantage, by reducing its dependence on external suppliers, which means that it can now better ensure that products are available, and that it can also improve its quality control over the entire value chain and rationalise its end product costs.

In terms of quality control, Solaria uses manufacturing and testing standards which are sometimes even more stringent than the sector's mandatory quality standard certifications. In order to meet its extensive pipeline of projects and committed purchase orders, Solaria is currently investing in increasing its production facilities.

The Solaria Research & Development Centre, located in Puertollano, Spain is now developing new technologies in partnership with some of the country's most prestigious universities. Some of the areas where Solaria is working to make the costs of solar energy competitive with conventional electricity include the reduction of material costs, increased scale, and improvement in cell efficiency and manufacturing techniques. Thanks to the efforts of companies like Solaria, solar photovoltaic energy in matured and regulated markets is becoming more and more competitive, leading to a reduction of generation costs, with grid parity set to be achieved in the next few years. In some countries, Solaria estimates that this may even occur as early as 2010, confirming that solar photovoltaic energy will have a major role to play in addressing the two global challenges of climate change and energy security.

### A halt in the solar boom

But the fiesta came to a sudden end with the announcement by the government in September 2008 that it was cutting the feed-in tariffs, and setting a 500MW ceiling on photovoltaic projects, in a bid to restore a degree of control over the renewable energy sector and to reduce spending on subsidies at a time of pressure on public finances.

"Spain has had runaway growth, the growth has been so tremendous that it just wasn't sustainable," says Ben Hill, VP of Sales and Marketing Europe for Chinese photovoltaic

module producer Trina Solar. "Spain at the height of last year represented 30% of our global sales". Hill estimates that only 250MW will be installed in Spain this year, compared to 2,400MW in 2008.

Combined with the financial crisis in Spain, the sudden collapse of the photovoltaic bubble and the drop in demand have resulted in tough times for Spanish manufacturers this year.

But after initial protests, voices from some of the stronger companies and institutions in the Spanish solar power sector say that the clampdown on subsidies may be just what the sector needed, so that it can now focus on the two major challenges of internationalization and achieving competitive costs with conventional energy, or grid parity.

"Governments will have increasingly fewer resources for subsidies, and we were certain that the subsidies that the photovoltaic industry received would not last forever," says Enrique Díaz-Tejeiro, chairman of leading solar panel manufacturer Solaria.

In response to the crisis, Solaria has started to make its own solar cells, in order to better control costs, and to step up expansion overseas. "The company has changed tremendously in the last 6 months," Díaz-Tejeiro says.

*Solaria modules manufacturing plant, Puertollano.*

"We have created a structure that focuses on the optimization of our costs, on the internationalization of the company, on entering mature and emerging markets, and on vertical integration."

That is the path that successful Spanish companies in the photovoltaic sector will now have to pursue, in order to remain competitive, says José Javier Armendáriz, director general of CENER, the National Renewable Energy Center. "I think the sector has to have a transition to adapt to the new regime, and develop technologies and processes that serve to reduce the cost of solar panels."

Meanwhile, landmark solar thermal developments are continuing apace. Torresol Energy, jointly owned by Spanish engineering group Sener, which designed the Andasol plant, and by the state of Abu Dhabi, is constructing the world's first plant to use central tower and salt receiver technology. Construction on the 17MW plant near Seville started in November 2008, and it should be operational in 2012.

And there is little doubt that the development of the new industrial sector of solar power remains a strategic objective for the Spanish government.

"The government of Spain has always said that the development of renewable energy in Spain reflects an industrial plan, not just an energy plan," says Álvaro Llorente, director general of Torresol Energy. "The state is investing heavily in the sector for energy reasons and also to enable industrial development in technology and components, so that Spain can be a leader in the market and export this technology."

"The financial assistance that renewable energy enjoys now will not last forever and it will have to fall," Llorente adds, "but we have to be able to accompany that fall in tariffs with more efficient technology…in these first few years we will have to be patient and constantly reduce costs."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