Global Corporate Research
11 April 2007

Capturing the gains from carbon capture

Sequestering greenhouse gas will create a major industry over the next five years

Corporate Research

Marc Levinson[AC]
(1-212) 622-5552
marc.levinson@jpmorgan.com

- Carbon sequestration—the burying of carbon dioxide captured from power generation and manufacturing—is likely to develop into an extremely large industry in the face of mounting concern about climate change.

- Investor interest in climate change has so far centered on utilities and fossil-fuel producers. This report seeks to widen this focus and look at opportunities for the industrial companies that are staking out roles in the infant capture-and-sequestration industry.

- Many methods of carbon capture involve integrated gasification combined cycle (IGCC) coal power plants. IGCC technology is improving rapidly and is becoming attractive to generators.

- The financial viability of carbon sequestration depends entirely upon the costs firms face for emitting carbon dioxide into the atmosphere. The projected cost of emissions may make sequestration commercially attractive in Europe as early as 2013.

- A variety of legal uncertainties must be resolved in both Europe and the US before carbon sequestration becomes practical. We expect most new US power plants to be designed to accommodate capture and sequestration at a later date, but not to have those facilities installed at the time of construction.

- We think that carbon capture and sequestration will create highly significant business opportunities for oil-field service companies with proprietary technology, such as **Halliburton** and **Schlumberger**; for construction and engineering companies with expertise in chemical engineering, such as **Washington Group** and **Fluor**; for designers and manufacturers of coal-burning power plants, notably **Alstom**, **General Electric**, and **Siemens**; for chemical companies such as **Praxair** that have expertise in membrane and filter technologies; and for oil producers that will benefit both by using carbon dioxide for enhanced oil recovery and by charging utilities to sequester CO_2.

www.morganmarkets.com

J.P. Morgan Securities Inc.

Marc Levinson
(1-212) 622-5552
marc.levinson@jpmorgan.com

Companies mentioned in this report

Company	Analyst	Equity recommendation	Price 9-Apr-07	Involvement in carbon capture and sequestration
Alstom	Andreas Willi	UW	€ 99.75	Post-combustion capture; oxygen-fuel combustion
Chevron	Katherine Lucas	N	$75.49	Sequestration; enhanced oil recovery
ConocoPhillips	Katherine Lucas	N	$68.58	Gasification technology
Denbury Resources	Joe Allman	OW	$30.84	CO_2 pipelines; enhanced oil recovery; owns natural CO_2 source
Dresser-Rand	Kevin Pollard	OW	$31.68	Compression for CO_2 pipelines and injection
Eastman Chemical	Jeff Zekauskas	N	$65.00	Gasification; pre-combustion capture
Emerson Electric	Steve Tusa	N	$42.72	Controls and process management for injection.
Fluor	Curt Woodworth	N	$91.72	Design and construction of post-combustion capture
General Electric	Steve Tusa	OW	$34.78	Standardization of IGCC plants; post-combustion separation
Halliburton	Michael LaMotte	N	$32.60	Injection wells
Honeywell	Steve Tusa	UW	$47.11	Methods to remove CO_2 from flue gas in post-combustion capture
National Oilwell Varco	Michael LaMotte	N	$79.63	Piping and coatings for CO_2 transport and injection
Occidental Petroleum	Katherine Lucas	N	$49.68	Enhanced oil recovery
Praxair	Jeff Zekauskas	N	$63.72	Membranes and process design for all carbon-capture methods
Schlumberger	Michael LaMotte	OW	$71.57	Injection wells; CO_2 mineralization
Shaw Group	Scott Levine	N	$29.32	Design and construction
Siemens	Andreas Willi	OW	€ 81.99	IGCC plant design and equipment
Washington Group	Scott Levine	OW	$64.74	Design and construction

Source: JPMorgan.

The birth of a major industry

Heightened concern about climate change is giving rise to an entirely new industry dedicated to capturing and storing greenhouse gases that would otherwise be emitted into the atmosphere. Over time, we anticipate that carbon capture and sequestration (CCS) will develop into an extremely large industry, involving hundreds of chemical-type plants and extensive pipeline networks.

Many major industrial corporations are now making investments with the aim of becoming significant players in this emerging industry. In the near term, these investments are almost entirely exploratory, and we see little prospect of substantial revenue or profit over the next five years.

We think the rising cost attached to greenhouse-gas emissions could make CCS commercially attractive in Europe as early as 2013. If this judgment proves correct, and if the technology is demonstrated, contractors and suppliers may begin to book sales early in the next decade. Companies that develop expertise or proprietary technology may gain important market opportunities as the demand for carbon sequestration expands.

This report is intended to assist investors in understanding this developing market. We explain some of the processes by which greenhouse gases can be captured and stored and review the economics underlying the industry. We then look at the efforts of individual firms to become involved in carbon sequestration and offer recommendations for investors with the long time horizons essential for investment in this sector.

A response to climate change

Carbon capture and sequestration is a concept developed in response to the intense concern about climate change. Numerous scientific studies over the past two decades have found high and rising concentrations of carbon dioxide, methane, and certain other “greenhouse gases” in the atmosphere. Evidence strongly indicates that these greenhouse-gas concentrations are leading to significant rises in temperatures on earth. Most greenhouse gases persist in the atmosphere for decades or longer, so emissions today will contribute to climate change for years into the future.

Reversing global warming will require large reductions in emissions of greenhouse gases from fossil-fuel combustion. Carbon dioxide (CO_2) is the largest single contributor to the greenhouse-gas buildup in the atmosphere. Coal-burning power plants are by far the largest source of greenhouse-gas emissions (Table 1), and, because of their size, are also among the easiest sources for governments to target. For these reasons, regulatory schemes in Europe and parts of the United States, and proposed schemes in other parts of the world, devote special attention to controlling CO_2 emissions from coal-fired generation.

Table 1: Major stationary sources of CO2 emissions worldwide

Process	Number of sources	Total emissions (Mt/yr)
Power generation	4,943	10,539
Cement production	1,175	932
Petroleum refining	638	798
Iron & steel production	269	646
Petrochemical production	470	379
Oil and gas processing	Unknown	50
Other	90	33
Ethanol and bioenergy	303	91

Source: IPCC.

In principle, CO_2 emissions from coal-burning power plants can be reduced in three main ways.

Alternative sources of power: The simplest way to reduce CO_2 emissions is to burn less coal, substituting sources of generation that have lower or no emissions, such as natural gas, uranium, and wind. We think these alternatives are unlikely to result in lower coal consumption over any meaningful time horizon, given the large installed base of coal-fired plants and the strong growth in electricity demand. In the United States, the US Department of Energy forecasts that nearly 40 gigawatts of new coal-fired capacity will come on line by 2020. Even if some of these planned units are never built, reductions in the use of coal from current levels will likely be difficult to achieve.

Greater efficiency in coal-fired generation: Technological improvements that increase the amount of electricity generated from a given volume of coal have the potential to restrain coal consumption. Efforts to improve thermal efficiency of power plants are under way at many locations. Typically, this involves installing new “supercritical” (and, eventually, “ultrasupercritical”) boilers that operate under higher pressure, or recovering and reusing heat from stack gas. These advances, which can increase generating efficiency by as much as 35%, should slow the growth of coal consumption. If, however, global coal-fired generating capacity increases 25% by 2020, as the US Department of Energy projects, improved efficiency in new and rebuilt plants is unlikely to reduce overall emissions from coal-fired plants below current levels.

Carbon capture and sequestration: The third approach involves “capturing” carbon dioxide produced in power generation before it escapes into the atmosphere. The CO_2 can then be sequestered, or stored, in such a way that it causes no environmental harm. Sequestration would be required for several centuries, until emissions reductions have succeeded in lowering the concentration of CO_2 in the atmosphere. Capture and sequestration seem to us likely to be part of any meaningful effort to achieve absolute reductions in CO_2 emissions.

The basics of capture and sequestration

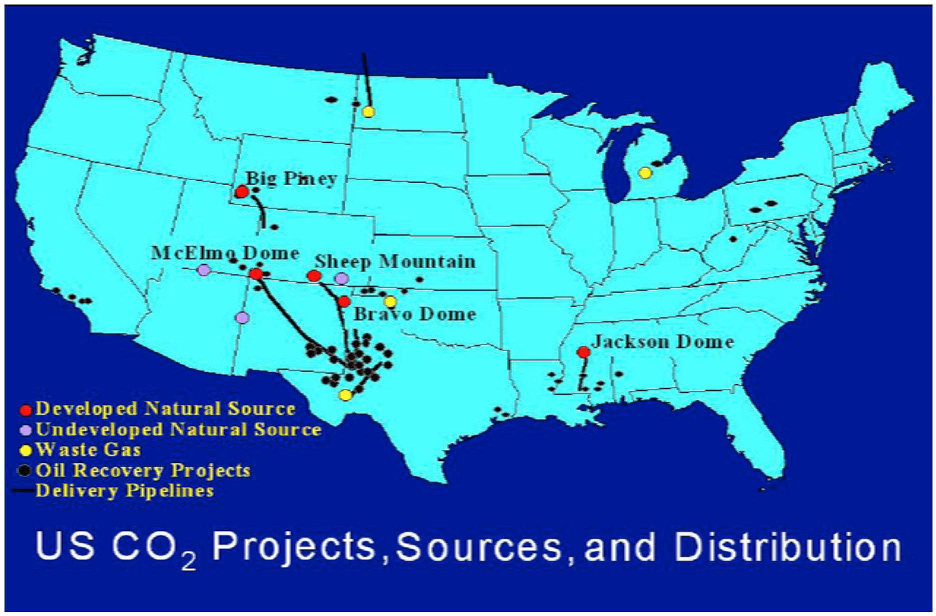
A number of projects that involve the capture and storage of carbon dioxide have been built in various parts of the world. All of these are small in scale. In the United States, carbon capture and sequestration has been in use for three decades, for

Marc Levinson
(1-212) 622-5552
marc.levinson@jpmorgan.com

JPMorgan

reasons unrelated to climate change. In these projects, the carbon dioxide generally is captured from natural sources and then injected into oil fields. This process, known as enhanced oil recovery, can increase the amount of oil recovered from an average field by as much as 50%. The oil producer typically pays for capture and injection, and then profits from the resultant increase in oil output. Enhanced oil recovery with CO_2 injection is in use in approximately 85 locations in the US (Figure 1).

Figure 1: Carbon capture and sequestration projects in the US



Source: Statoil.

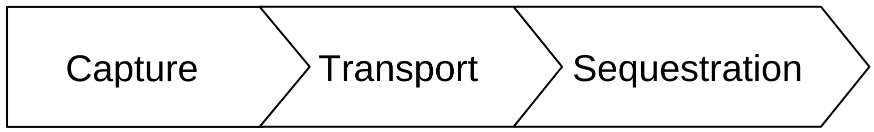
All of the existing carbon sequestration projects are small. The largest existing project in the world, undertaken by the Norwegian oil company Statoil in the North Sea since 1996, annually separates and stores less than 1 million metric tons of CO_2 resulting from natural gas production—an amount equal to a few months' emissions from a coal-fired generating station. The total amount of carbon dioxide being captured and stored in existing US enhanced oil recovery projects is equivalent to one or two months of a single power plant's emissions. Three other experimental projects aimed at capturing and storing energy-related emissions are operating in Canada and Europe.

To our knowledge, no large-scale CCS system is in routine operation anywhere. Thus, while many different CCS technologies are in use or under development, none of them has been demonstrated at the scale required to serve a full-size coal-burning generating plant. The US utility industry is seeking to obtain government support for a full-scale demonstration of CCS in energy legislation now being debated in Congress.

CCS involves three distinct steps with quite different technical and economic characteristics. Capture involves separating the CO_2 from other gases at the source, purifying it if necessary, and concentrating it. This phase, which has the greatest technological content, is likely to be the province of chemical and chemical-

Marc Levinson
(1-212) 622-5552
marc.levinson@jpmorgan.com

engineering companies. Once concentrated, the CO2 will be handed off to a pipeline operator for delivery to a storage site. This phase requires pipeline construction, flow monitoring, and other skills in which pipeline operators specialize. The sequestration phase involves injection into the ground and long-term monitoring, and is likely to be conducted by large oil and oilfield service companies.



Carbon capture

Carbon dioxide can be captured from power plants and other sources by one of three principal methods:

- **Pre-combustion capture.** Rather than being fed directly into the power plant, coal can be gasified into a "syngas" composed predominantly of hydrogen and carbon monoxide. This gas can be "water shifted" to produce a mixture of carbon dioxide, hydrogen, and other gases. The carbon dioxide can then be captured for storage, while the hydrogen could be put through a turbine or fed to fuel cells to generate power. Gasification technology is used today in small-scale plants that do not produce electricity. Use at larger scale requires construction of integrated gasification combined cycle (IGCC) plants, probably involving oxygen-fuel combustion. A handful of relatively small IGCC plants are in operation around the world, and generators are proposing to build approximately 25 commercial-size plants in the United States and a large number elsewhere. With present technology, IGCC plants are expected to be able to capture 75-80% of CO_2 emissions with little loss of efficiency, but a recent report indicates that recovery rates above 85% will lead to significant efficiency loss. Pre-combustion capture is also suitable for gas-fired generating plants, although with higher costs per ton of CO_2 captured.

- **Oxygen-fuel combustion.** This technology involves designing the power plant to burn coal with pure or nearly pure oxygen. If this is done, the resulting flue gas will consist principally of CO_2 and water vapor, making the CO_2 easy to capture once the water vapor is condensed. This approach requires a costly oxygen separator attached to the plant to remove nitrogen from the combustion gas. Oxygen separators can be retrofitted on existing power plants, but tend to reduce efficiency. The separation process also consumes as much as 15% of the electricity generated by the plant.

- **Flue gas separation.** Carbon dioxide accounts for 10-12% of the flue gas emitted by conventional coal-fired power plants. Separation, as the name suggests, involves capturing the CO_2 from the smokestack. Separation is essentially a chemical engineering process, in which the flue gas passes through a chemical solvent that absorbs the carbon dioxide. The solvent is then piped to an adjacent unit in which steam is used to separate out the CO_2 in highly concentrated form. The concentrated CO_2 is then compressed for shipment, while the solvent is reused. In some trials, membranes rather than steam are used to separate out the CO_2, and this approach is now the subject

Marc Levinson
(1-212) 622-5552
marc.levinson@jpmorgan.com

of considerable research. A number of other approaches also have been tried. Some separation technologies are energy intensive, necessitating construction of a larger generating plant and partially defeating the goal of reducing CO_2 emissions.

Carbon transport

Once captured, the concentrated carbon dioxide would be transported by dedicated pipeline to a storage location. Pipeline transportation of carbon dioxide already is a technologically mature industry, with approximately 3,500 miles of CO_2 pipelines now in use in the United States. CO_2 pipelines and pipeline equipment are technically quite similar to those in use for natural gas, so there may be relatively little technological innovation in this part of the capture-and-storage process.

Expanded use of carbon capture and sequestration would likely lead to a massive expansion of pipeline networks. Some estimate that the future network for transporting CO_2 will be similar in scale to that now in place for natural gas, which in the United States now incorporates 300,000 miles of transmission pipe. We anticipate that carbon sequestration could bring significant new business for steel pipe manufacturers, manufacturers of pipe installation equipment, and pipeline operators.

Sequestration

After being transported to an injection site, the CO_2 would be injected 800 meters or more into the ground. Such injections have occurred for many years, but on limited scale. Widespread adoption of carbon capture and sequestration would lead to a quantum change in the amount of injection and will stimulate new technology to identify injection locations and monitor sequestered gas.

Currently, oil producers inject carbon dioxide as a tertiary recovery method to increase extraction from an aging field in a process known as CO_2 flooding. In this process, water is first injected to restore reservoir pressure, followed by CO_2. The concentrated CO_2 expands and reacts with the oil, lowering the viscosity, increasing the flow rate, and easing transport to the production well. Related enhanced oil recovery processes include thermal recovery and chemical injection. A well that is a good candidate for CO_2 flooding is deep (>2,000 ft), with API oil gravity greater than 22-25 degrees, and remaining oil saturation greater than 20%. While the amount of CO_2 now used in this process is small, the technology is well established.

Oil and gas fields are also being used for CO_2 storage where no enhanced oil recovery is contemplated. This mainly involves CO_2 mixed with hydrogen sulfide, which is a byproduct of oil and gas production. At some sites, this waste mixture is reinjected into the depleted oil and gas reservoirs for storage.

If CCS is to bring about significant reductions in CO_2 emissions, very large amounts of storage will be required, probably far outstripping the amount available in oil fields. Carbon dioxide also could be stored in abandoned coal mines, in depleted natural-gas fields, and in very deep saline formations as well. The availability of suitable underground storage space is unknown, as only isolated geological investigations have been conducted. Initially, at least, oil-field storage

Marc Levinson
(1-212) 622-5552
marc.levinson@jpmorgan.com

seems likely to be the most viable alternative in the US, whereas saline storage appears the most promising alternative in Europe.

Scientists believe that CO_2 also could be sequestered in ocean depths. Below 3,000 meters, compressed CO_2, in liquid form, is denser than seawater. The liquid CO_2 would be expected to remain trapped for decades or even centuries. However, the CO_2 could potentially increase the ocean's acidity, with unknown consequences on marine life. In any case, the electric generators with the greatest interest in developing carbon capture and storage are aware of the potential environmentalist backlash against injecting CO_2 into the ocean, and are not actively promoting the ocean as a storage location.

One important difference between existing methods of carbon sequestration and future practices lies in the amount of monitoring required. With enhanced oil recovery, the possible escape of carbon dioxide into the atmosphere is of no great concern. If sequestration is undertaken for environmental purposes, however, those storing the CO_2 will need to make sure it remains where it was stored, potentially creating a market for new types of instrumentation.

Legal obstacles

Carbon storage faces important legal obstacles. The two most important concern liability and property rights.

Liability arises as a major issue because of the possibility of leakage from a storage reservoir over the many decades during which storage would be required. Leakage could occur either through mechanical failure or through a geological event, such as an earthquake or a volcanic eruption that could allow concentrated CO_2 to escape to the surface. Although CO_2 is not toxic, the sudden release of a large amount of CO_2 could create an intolerably high concentration of CO_2 in the air around the escape site, causing death by asphyxiation. In addition to whatever direct damage they caused, companies held liable for leakage would presumably face significant fines for discharging CO_2 into the atmosphere without permits.

Underground stores of CO_2 could also create liability even without leakage into the atmosphere. In theory, CO_2 could leach into groundwater supplies and could contribute to chemical reactions that could weaken rock structures and eventually alter the surface.

Liability shields are thus critical to the widespread use of CCS. US utilities have been unwilling to participate in large-scale CCS trials without being shielded from liability, and they envision a future in which they would shed all responsibility for the CO_2 once it enters a pipeline. The various equipment and service vendors exploring CCS, however, have been unwilling to accept unlimited liability in perpetuity. This impasse threatens to delay the development of CCS in the United States. In Europe, utilities are seeking assurances that their liability will be limited in the event sequestered CO_2 leaks into the atmosphere. European utilities have proposed a mechanism similar to that in place for nuclear power plants, under which

Marc Levinson
(1-212) 622-5552
marc.levinson@jpmorgan.com

the utility bears the first €200 million of liability for an accident and the government is responsible for costs above that amount.

The property rights question concerns ownership of the underground spaces, known as "pore space," into which the concentrated CO_2 would be injected. In some US states, the pore space left by oil and gas production is thought to be owned by the owner of the mineral rights. In other states, it is believed to be owned by the owner of the surface rights, and in certain states ownership is legally unclear. Large-scale sequestration of carbon dioxide cannot proceed until the courts in various states issue definitive rulings about the ownership of pore space, or until state legislatures act on the subject.

The property-rights questions are less problematic in Europe, where underground geologies are uniformly state property and mineral-rights holders control only extraction rights for a limited time period. However, CCS in Europe faces legal issues related to rights-of-way for pipelines and procedures for granting access rights to depleted oil fields and saline aquifer structures. Additionally, we expect European utilities to be at the forefront of the political push to sort out the legislative side of rights-of-way for pipelines and access rights to depleted oil fields and saline aquifer structures.

Property-rights issues may lead to the reopening of closed-in oil fields in Texas. According to a staff interpretation supplied to us by the Texas Railroad Commission, the rights to pore space in a reservoir productive of oil or gas are controlled by the owner of the mineral rights, whereas the rights to pore space in other locations are controlled by the owner of surface rights. The Railroad Commission staff cautions that it is unaware of any case law or statute that definitively addresses the issue. Under its staff interpretation, however, once the storage of carbon dioxide becomes a potential revenue source, mineral-rights owners will have an incentive to reopen low-volume wells in order to maintain control of the underground storage space.

There also are unresolved legal issues concerning the regulation of CO_2 pipelines and storage facilities in the United States. The Federal Energy Regulatory Commission (FERC), the economic regulator of interstate gas and oil pipelines, disclaims jurisdiction over pipelines carrying products that are not hydrocarbon based or are not used for energy purposes.[1] Such pipelines operating as common carriers—offering their services to any customers—have their rates overseen by the US Surface Transportation Board, but a pipeline moving CO_2 from a single power plant to a sequestration site would not face rate regulation. The US Department of Transportation's Office of Pipeline Safety is responsible for safety regulation of interstate pipelines. It reports an average of 2-3 minor incidents per year involving CO_2 pipelines, typically involving corrosion, failed welds, or equipment failures.

Underground injection in the US is regulated by the US Environmental Protection Agency or state agencies in order to protect drinking water. However, it appears that no federal or state agency currently has authority over underground storage sites to assure that the sequestered CO_2 does not escape to the surface as a result of poor maintenance. In all probability, a new regulatory structure

1. Texas Petrochemical Pipeline LLC, 107 FERC Sec. 61, 151, May 10, 2004.

will have to be created. The European Union also has no regulator with clear authority for monitoring underground CO_2 storage sites.

The Economics of CCS: The Cost Side

The embrace of CCS, if it occurs, will be almost entirely a function of the price attached to greenhouse-gas emissions. At present, these emissions have a very low price within the European Union, and are free everywhere else in the world. As a result, users of concentrated carbon dioxide, such as oil producers pursuing enhanced oil recovery, must purchase it from electric generators, which otherwise have no reason to capture it. This situation will not persist, in our view. In the future, we believe the costs of capturing and sequestering carbon dioxide will have to be borne by owners of coal generation, not by the users of CO_2.

Capture and sequestration is not necessarily the lowest-cost means of avoiding CO_2 emissions. In fact, it would probably be quite costly if attempted with conventional pulverized-coal generating plants. However, technological innovations are expected to make some CCS technologies cost competitive, especially when they are integrated into coal-fired plants designed for capture of carbon dioxide (Table 2).

Table 2: Estimated net cost per ton of CO_2 avoided, 2030

Technology	€/t CO_2	\$/t CO_2
CCS on new coal plants, with enhanced oil recovery	€15-€20	$20-$27
Co-firing of biomass in coal plants	€20-€30	$27-$40
Wind power, including backup generation	€ 22	$29
Solar	€ 24	$32
CCS at new coal plants, no oil recovery	€25-€41	$33-$45
CCS retrofitted to existing coal plants, with enhanced oil recovery	€27-€40	$36-$53
CCS retrofitted to existing coal plants, no oil recovery	€27-€41	$36-$45
CCS on new gas-fired generator, with enhanced oil recovery	€30-€40	$40-$53
CCS retrofitted to gas-fired generators, no oil recovery	€40-€60	$53-$80

Source: Vattenfall, JPMorgan.

Note: Constant euros; assumed exchange rate €1=$1.33.

Using current technology at current costs, installing and operating CCS systems will raise the cost of generation from a conventional coal plant on the order of 50%. The Intergovernmental Panel on Climate Change (IPCC), an international scientific group working on the subject, estimated in 2005 that capture and geological storage would add $0.01-$0.05 per kilowatt hour ($10-$50 per megawatt hour) to the cost of generating electricity from a conventional coal plant. JPMorgan estimates that the average cost of coal generation in the United States is around $0.05 per kilowatt hour, including taxes and interest charges. The IPCC estimate implies an increase of 20-100% in the cost of generating electricity from coal. A survey by energy scientists at the Massachusetts Institute of Technology revealed slightly higher estimates, with the studies analyzed estimating a mean increase of 87% in the cost of conventional coal generation from adding CCS.

On a volume basis, estimates of the cost of carbon capture and storage depend heavily on specific assumptions about the generating plant. For a new plant designed with CCS in mind, the Intergovernmental Panel on Climate Change estimates the cost of capture and storage at $30-$70 per ton of carbon dioxide avoided. If retrofitting of older plants is required, estimated costs are considerably higher. Vattenfall, a Swedish utility, offers estimates in a similar range, €25-€60 ($34-$80) per ton of emissions avoided in an existing plant, and €15-€40 ($21-$54) for future plants designed around CCS. "Capturing" the CO2 is by far the most expensive part of the process, which is why new generating plants designed to facilitate carbon capture will have a significant cost advantage (Table 3).

Table 3: Estimated cost of carbon capture and storage

Process	Cost range per metric ton CO_2 captured	Comments
Capture from power plant	$15-$75	Net cost compared to the same plant without capture
Transportation	$1-$8	Cost per 250 km via pipeline
Geological storage	$0.5-$8	Excludes potential revenues from enhanced oil recovery
Monitoring of storage	$0.1-$0.3	Depending upon regulation
Measured costs	$16.60-$91.30	
Costs not measured		
Liability		Availability of insurance uncertain
Remediation		Availability of insurance uncertain
Purchase of rights to underground storage		May be costly at large scale

Source: IPCC and JPMorgan.

Note: The cost per ton of emissions avoided is higher than these ranges, because of the energy required to capture and store CO_2.

All of these cost estimates omit factors that could drive the ultimate cost of carbon sequestration higher. Unless legislators limit liability for participants in sequestration schemes, the cost of insurance may be substantial, assuming that insurance is even available. There is some risk that underground storage will contaminate ground water supplies, and the potential cost of mandatory remediation will need to be factored into cost estimates. All known estimates of sequestration costs appear to assume free use of pore space or other underground storage, and this seems to us an unrealistic assumption; if CCS is undertaken on a large scale, underground sites with desirable geology will become valuable resources, and their owners can be expected to charge for their use.

The cost of carbon capture is expected to decline in the future as purpose-built generating plants arrive and as new technologies come into use. The attractiveness of carbon capture and storage depends both on such cost reductions and on the cost of the main alternative, emitting carbon dioxide into the atmosphere.

The Economics of CCS: The Payoff

Regulations are slowly beginning to attach costs to generators' carbon-dioxide emissions. We expect that within the next six or seven years, emissions costs in the European Union will reach the level at which carbon capture and sequestration starts to become economically viable. In the United States, costs attached to CO_2 emissions are unlikely to work in favor of CCS for at least two decades, barring rapid declines in capture costs.

European Utilities Equity Research

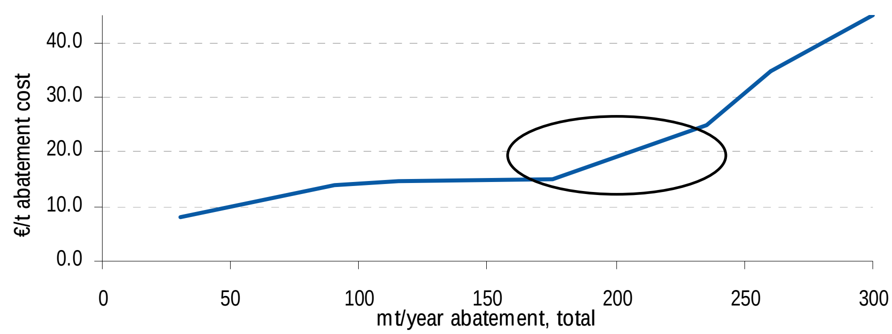
Chris Rogers
(44 20) 7325 9068
christopher.g.rogers@jpmorgan.com

Generators in the EU have been required to obtain tradable CO_2 emissions permits since 2005. Initially, each source was allocated permits based on its reported historical emissions. These reports appear to have been exaggerated, leading to an overallocation of permits. As a result, permits have traded as low as €0.75 per metric ton, a price that provides no incentive for emissions control.

In "Phase 2" of its emissions trading scheme, covering 2008-2012, the EU plans to reduce the number of permits issued. (A permit allows the holder to emit one metric ton of CO_2 during the five-year period, and is not limited to a specific year.) We believe that the number of permits available will force reductions averaging 155-210 million tons per year from current levels. In addition**,** airlines are to come under the scheme from 2011, increasing the shortfall by a further 85 million tons per year. [2]

We estimate that emissions reduction of this magnitude will bring the average cost of a permit for the 2008-2012 period to around €20 ($26) per ton of carbon dioxide emitted (Figure 2). This will have the effect of forcing up the price of coal-fired power and will encourage utilities to shift some generation from coal to gas, where feasible. However, we do not believe that the cost of emissions permits in the 2008-2012 period will be high enough to make CCS a commercially viable alternative.

Figure 2: EU emissions abatement goal will drive cost of permits



Source: JPMorgan estimates.

The price attached to greenhouse-gas emissions in Europe is likely to make CCS far more attractive in "Phase 3" of the emissions trading scheme, starting in 2013. The waters here are somewhat murky. The EU has an announced target of reducing all greenhouse-gas emissions 20% below the 1990 level by 2020, but it is not clear whether all of that reduction will come from sectors currently covered by the emissions trading scheme (utilities, glass, paper, cement, oil refining, airlines from 2011) or whether other sectors will be required to reduce emissions as well. The EU will shift to a more ambitious target, reducing emissions 30% below 1990 levels, if a new international agreement on climate change is reached.

While the details are far from certain, we regard it as highly likely that the number of permits available for 2013-2020, on an annual average basis, will be far lower than for 2008-2012. We also think it likely that utilities, which received

2. For details on the EU emissions trading scheme, see the JPMorgan report *All you ever wanted to know about carbon trading, vol 4 pt 1*, December 14, 2006.

"free" permits to cover their historical emissions in the 2005-07 start-up phase of emissions trading and will receive "free" permits for around 65% of historical emissions in Phase 2, will be treated much less generously in Phase 3. We expect utilities will be given "free" permits equal to no more than 25-40% of historical emissions, and perhaps none at all.

We expect the price of greenhouse-gas emissions permits to average €25-40 ($34-53) per ton over the 2013-2020 period, based on a reasonable set of assumptions. As a permit can be used at any point over those eight years, it is not necessarily the case that permit prices will rise gradually from year to year. On the contrary, prices likely will begin adjusting to the new permit regime as early as 2013.

Our forecast of permit prices indicates that some methods of carbon capture and sequestration may be commercially viable for emissions reduction in Europe as early as 2013. As the technology is proven at commercial scale, we expect to see new coal-fired plants incorporating CCS enter service in Europe as early as 2014-2015, and to account for almost new coal plants in Europe by late in the coming decade.

Our expectations of CCS in the United States are less aggressive, because we expect emissions costs to be far lower than in Europe. As a result, we expect that many new coal-fired plants will be designed to incorporate carbon capture and sequestration at a later date, but we do not think that installation of CCS will be viable in the absence of direct government subsidies.

Two regional schemes to regulate CO_2 emissions, one in the Northeast and the other in California, will soon enter into force in the US. The rules for the 10-state Northeastern scheme, known as the Regional Greenhouse Gas Initiative, will impose costs on generators' CO_2 emissions from 2009, but effectively set the maximum cost at $7 per ton through 2018. California is to impose limits on greenhouse-gas emissions from 2012, when generators probably will become subject to a permitting system. However, detailed regulations will not be issued until 2009, so the potential cost imposed on emitters cannot readily be estimated.[3]

JPMorgan expects Congress to adopt a nationwide plan to control greenhouse-gas emissions within the next couple of years. This seems likely to include a national cap on emissions and a system of tradable permits, similar to the EU and RGGI schemes. However, we expect the new limits to be phased in very gradually, and to have little cost impact on generators before 2020.

Elsewhere in the world, no binding restrictions on CO_2 emissions are in place. While we expect Australia, Japan, China, and other countries to adopted emissions-trading schemes over the next few years, all of these schemes are likely to be introduced in phases in order to avoid economic dislocation. This necessarily means that the cost of emissions will remain low for the foreseeable future.

Given the low cost of carbon-dioxide emissions, carbon capture and sequestration currently make sense only for new plants with long anticipated

3. For details on pending US regulations, see the JPMorgan reports *Warming to rules on climate change*, September 27, 2006, and *Global Utilities: Trading climate change*, March 5, 2007.

lifetimes. Even then, some operators will find it preferable to build generating plants designed to facilitate carbon capture ("CCS ready"), while postponing construction of capture-and-sequestration facilities until such time as the cost of carbon-dioxide emissions justifies the expenditure. In the absence of subsidies, the economics do not justify CCS at existing facilities, except perhaps in the event of a major overhaul designed to extend plant life for decades.

We note that widespread use of CCS will also have a payoff for oil producers and service companies. On the one hand, it will lower the costs and improve the feasibility of CO_2 flooding. Currently, oil producers have to bear the cost of expensive machinery to capture carbon dioxide. Should carbon capture become legislatively mandated, this expense will be shifted on to the owners of coal-fired generators, making CO_2 flooding more affordable. Sequestering the CO_2 will provide a new source of revenue for oil producers, who will be able to charge for underground storage space, and for oilfield service companies, which may be able modify enhanced oil recovery technology for the purpose.

The CCS Industrial Complex

As the above discussion indicates, firms participating in the carbon capture and sequestration market have few near-term revenue prospects. The International Energy Agency has identified only 18 significant CCS projects likely to get underway around the world over the next decade (Table 4). Investments related to carbon capture and sequestration should thus be regarded as developmental, as companies seek understand the emerging market and position themselves to exploit future revenue opportunities.

Table 4: Selected demonstration projects incorporating capture and sequestration

Company	Location	Fuel	Output (MW)	Cost (millions)	Technology	Start date
BP	Peterhead, Scotland	Natural gas	350	$400	Pre-combustion capture; oilfield storage	2010
BP	Carson, California	Petcoke	500	$1,000	IGCC; pre-combustion capture; oilfield storage	2011
China Huaneng Group	Undetermined	Coal	100	Unknown	IGCC; pre-combustion capture	2015
E.ON	Killingholme, England	Coal	450	£1,000	IGCC; may include pre-combustion capture	2011
Scottish & Southern	Ferrybridge, Scotland	Coal	500	£250	Retrofit plant and make "capture-ready"	2011
FutureGen	Undetermined	Coal	275	$1,000	IGCC; pre-combustion capture	2012
General Electric	Poland	Coal	1,000	Unknown	IGCC; pre-combustion capture	Unknown
Statoil	Karstø, Norway	Natural gas	430	Unknown	Post-combustion capture; possible oilfield storage	2009
Statoil	Mongstad, Norway	Natural gas	280*	Unknown	Post-combustion capture and storage	2014
Nuon	Eemshaven, Netherlands	Coal/gas/bio	1,200	Unknown	IGCC; "option to capture"	2011
Powerfuel	Hatfield, UK	Coal	900	Unknown	IGCC; pre-combustion capture	2010
Centrica/Progressive	Teesside, UK	Coal/petcoke	800	$1,500	IGCC; pre-combustion capture	2009
SaskPower	Saskatchewan	Lignite	300	Unknown	Post-combustion or oxygen-fuel; oilfield storage	2011
Siemens	Germany	Coal	1,000	€ 1,700	IGCC; pre-combustion capture	2011
Stanwell	Queensland, Australia	Coal	100	Unknown	IGCC; pre-combustion capture and storage	2012
Statoil/Shell	Draugen, Norway	Natural gas	860	Unknown	Post-combustion capture; oilfield storage	2011
RWE	Germany	Coal	450	€ 1,000	IGCC; pre-combustion capture and storage	2014
RWE	Germany	Coal	1,000	€ 800	Retrofit; post-combustion capture or "capture-ready'	2016
AEP	Oologah, Oklahoma	Coal	450	Uknown	Retrofit with flue-gas separation; oilfield storage	2011

Source: International Energy Agency, company reports, press reports.
Note: * additional 350 MW of heat output.

These future revenue opportunities may prove to be extremely large. Carbon capture and sequestration on an environmentally meaningful scale will require the creation of a massive industry. A conventional 500 megawatt coal-fired generating station produces more than 4 million metric tons of CO_2 per year—and there are thousands of conventional coal plants around the world. In the transportation sector alone, by some estimates, sequestering 60% of the carbon dioxide produced by US coal-fired generating plants could require as large a pipeline network as that now used to transport oil. Adding a flue-gas separation unit to a traditional 400 megawatt coal plant would cost somewhere around $400 million.

The opportunity to cash in on CCS will extend to many different industries. Some industries may be able to meet this potential demand with existing products; the pipelines used to transport CO_2, for example, will probably be very similar in terms of materials and construction methods to those now used for natural gas. On the other hand, the growth of CCS is likely to bring considerable innovation in chemical solvents and membranes, design and construction of oxygen and flue-gas separators, and instrumentation systems to monitor underground storage facilities.

At the moment, there is little proprietary technology at work in carbon capture and sequestration—but that is likely to change very soon. On the following pages, we highlight companies that have significant involvement in this emerging field, and describe the different areas in which they hope to obtain proprietary advantage.

Investing in CCS

Carbon capture and sequestration, much like solar power, fuel cells, and hydrogen power, offers few prospects for investors concerned about near-term cash flows and earnings. Investors with longer time horizons, however, may find it opportune to enter a sector that is likely to experience very rapid growth over the coming decade.

We recommend that investors focus on technological potential as they scrutinize companies active in CCS. Some aspects of the capture-and-sequestration process, such as capture at power plants and monitoring of sequestration sites, are likely to see considerable technological advance. Other aspects, such as transportation of concentrated carbon dioxide in pipelines, are already well understood, and may offer little opportunity for further proprietary innovations.

Below, we highlight the strategies being followed by some of the companies actively engaged in research and development related to CCS. In most instances, companies appear to be concentrating on one or another part of the process:

Marc Levinson
(1-212) 622-5552
marc.levinson@jpmorgan.com

Capture > Transport > Sequestration

Carbon capture

European Capital Goods Equity Research

Andreas Willi
(44 20) 7325 4835
andreas.p.willi@jpmorgan.com

Alstom

Alstom is developing a process that uses chilled ammonia to capture CO_2 in the post-combustion stage. This process dramatically reduces the energy required to capture and isolate carbon dioxide. In laboratory testing sponsored by the US Electric Power Research Institute and others, Alstom's process has demonstrated the potential to capture over 90% of CO_2 at a cost far below that of other technologies. Alstom believes that the main advantage of its process is that it can be used to retrofit existing coal-fired plants as well as in construction of new plants.

Alstom signed an agreement with the US utility AEP to jointly develop a full scale commercial carbon capture project of up to 200 megawatts by 2011. The project will be implemented in two phases. In phase one, Alstom and AEP will jointly develop a "validation plant" that will capture up to 100,000 tons of CO_2 per year from flue gas emitted from AEP's 1300 mW Mountaineer Plant in New Haven, West Virginia. The captured CO_2 will be sequestered in deep saline aquifers at the site. This pilot is scheduled for start-up at the end of 2008 and will operate for approximately 12-18 months. In phase two, Alstom will design, construct, and commission a commercial-scale CO_2 capture system on one of the 450 mW coal-fired units at AEP's Northeastern Station in Oologah, Oklahoma. The system, scheduled for start-up in late 2011, is expected to capture about 1.5 million metric tons of CO_2 a year, commercially validating the technology. The captured CO_2 will be used for enhanced oil recovery.

Alstom is also active in oxygen-fuel combustion in conjunction with US Department of Energy research. After pilot tests at a 3 megawatt pilot plant in Connecticut, the company is now building a 30 megawatt validation plant together with Vattenfall, a generator, in Germany, and is developing a conceptual design for retrofitting an 80 mW coal-fired boiler for oxygen-fuel firing. If built, this would be the first commercial demonstration plant of its kind in North America. According to the company, its main research in this field involves combustion efficiency, heat transfer, boiler design, and environmental equipment.

US Integrated Oils and Refiners Equity Research

Katherine Lucas, CFA
(1-212) 622-6451
katherine.a.lucas@jpmorgan.com

ConocoPhillips

ConocoPhillips has a gasification technology called E-Gas intended for use in IGCC plants. The technology uses pet coke, coal, and other low-value hydrocarbons to make a synthetic gas consisting mainly of hydrogen, carbon monoxide, and carbon dioxide, with lesser proportions of water, nitrogen, methane, hydrogen sulfide, and carbonyl sulfide. The CO_2 and hydrogen sulfide are then separated in a removal system using a chemical solvent, methyldiethanolamine. The remaining gas can then be used to power turbines, while the hydrogen sulfide is turned into sulfur for sale. The carbon dioxide, which represents about 20% of the volume of the synthetic gas, can be compressed and piped to a sequestration site. ConocoPhillips is seeking to license this technology, but at this point it represents a very small portion of company's business portfolio.

US Chemicals Equity Research

Jeff Zekauskas
(1-212) 622-6644
jeffrey.zekauskas@jpmorgan.com

Eastman Chemical

Eastman is has been involved in coal gasification technologies since 1983, when it opened the first US commercial coal gasification facility in Kingsport, TN. A subsidiary, Eastman Gasification Services, specializes in development of coal-gas technologies. Eastman committed the greater part of its $43 million in 2006 research and development spending to develop its gasification operations. Eastman has not focused on the power generation sector as a market for its technology, although its expertise in design of gasification and capture systems may be relevant for power plants designed for carbon capture and sequestration.

Eastman's main interest in gasification involves harnessing byproducts other than CO_2 for use in downstream petrochemical applications. The company sees the value in supplying CO_2 for enhanced oil recovery in the US Gulf Coast region as minor compared to that of other coal gasification byproducts produced at Kingsport. The company is currently seeking a joint-venture partner to redevelop an existing ethylene cracker in Longview, TX into a gasification unit that would produce propylene feedstock for production of oxo-alcohols and solvents; the unit could readily be adapted to capture CO_2 for sequestration in Gulf Coast oilfields. The facility is expected to come on line in 2011.

Fluor

Small/Mid Cap Diversified Industrials

Curt Woodworth, CFA
(1-212) 622-6641
curtis.r.woodworth@jpmorgan.com

Fluor's Economine process, originally patented in the 1960s, uses a monoethanol-amine solvent to capture the carbon dioxide from flue gas. To date, the process has been used mainly in conjunction with natural-gas combustion, although there have been some trials with flue gas derived from coal. Fluor is involved in design and construction of the BP refinery project in Carson, CA, which incorporates carbon capture and sequestration. The latest version of its technology, Economine FG Plus, is being considered for a gas-fired combined heat-and-power plant being built by Statoil in Mongstad, Norway, at which 85% of the CO_2 emissions are to be captured and sequestered.

General Electric

Electrical Equipment and Multi-Industry Equity Research

Steve Tusa
(1-212) 622-6623
stephen.tusa@jpmorgan.com

GE is making big investments in carbon capture and sequestration, which it views as a game-changing technology. GE sees pre-combustion capture through IGCC as the biggest opportunity, potentially bringing it $75 billion of revenue in the 2010-2020 period. Although IGCC plants now bear a 20-25% capital-cost disadvantage compared with traditional pulverized coal, GE expects that situation to reverse as the cost of IGCC technology falls and as the addition of post-combustion capture raises the cost of pulverized coal plants.

For General Electric, IGCC holds two main attractions. First, it enables the company to capture a larger share of power-plant content: some 40% of the value of an IGCC plant is made up of products that GE sells (steam turbine, generator, gas turbine, gasification island), versus only 5% of the value of a pulverized coal plant (steam turbine, generator). Second, GE anticipates rapid advances in standardization, which are expected to drive costs down. Since 2004, when it acquired the enabling gasification technology from Chevron, GE has collaborated with Bechtel to develop a standard design for commercial-scale IGCC plants. If demand shifts in favor of IGCC, we think GE will easily be able top its record sale of 350 gas turbines in a single year, recorded in 2001. This figure would represent a doubling of the 175 units expected to be sold in 2007.

GE is heavily involved with the integration of IGCC into refineries. It is working with BP and Edison Mission Energy to convert petroleum coke from a refinery in Carson, California, into electricity in a 500 megawatt plant, with the captured CO_2 to be used for enhanced oil recovery. It is proposing to more than double the size of a 260 megawatt IGCC plant in Florida that opened in 1996, and we expect it to bid on two IGCC commercial demonstration plants that TXU proposed to build in Texas. Last year, it established a clean coal research center in Poland, providing a base for marketing its IGCC technology across Europe.

General Electric expanded its presence in post-combustion separation technologies through the 2004 acquisition of BHA Group, which makes filtration membranes and parts for air pollution control systems. However, it appears to view post-combustion capture as a business with much less potential than pre-combustion capture with IGCC.

Electrical Equipment and Multi-Industry Equity Research

Steve Tusa
(1-212) 622-6623
stephen.tusa@jpmorgan.com

Honeywell

Honeywell's UOP subsidiary, whose principal customers are in the oil refining industry, has a small US Department of Energy contract to develop a metal-based process to remove carbon dioxide from flue gas for post-combustion capture. Honeywell also owns the rights to a solvent called Selexol, made of a dimethyl ether of polyethylene glycol, which is used to remove CO_2 in the process of purifying hydrogen for use in fertilizers and refining. The process appears to lend itself to carbon capture for environmental purposes, although it is not presently being employed in that way.

US Chemicals Equity Research

Jeff Zekauskas
(1-212) 622-6644
jeffrey.zekauskas@jpmorgan.com

Praxair

Praxair is moving aggressively into carbon capture and sequestration, as it believes that some carbon-capture technologies are closely related to its core competence in industrial combustion processes. The company is involved in all three methods of carbon capture, pre-combustion capture, oxygen-fuel combustion, and flue-gas separation. It appears to be focusing on membrane-based technologies for pre-combustion capture in IGCC plants and for oxygen separation in coal-fired plants using oxygen-fuel combustion. Praxair is also seeking to develop carbon-capture systems for industrial facilities outside the power sector in the expectation that other industries will be subject to carbon emissions controls in the future.

Praxair is currently a major supplier of CO_2 for industrial uses and for enhanced oil recovery. This business eventually may be hurt by the ample supplies of CO_2 likely to come from generating plants, but we view this as a long-term issue in the US.

Construction and Engineering Equity Research

Scott Levine
(1-212) 622-5609
scott.j.levine@jpmorgan.com

ShawGroup

Shaw, an engineering and construction company that emphasizes both the electric generation and chemical manufacturing sectors, seems to us likely to take an important role in development of the CCS market. We note that the company has recently been involved in new power plant projects incorporating clean coal technologies, including the use of circulating fluidized bed boilers. Shaw also has expertise recovering greenhouse gases such as methane at landfills.

European Capital Goods Equity Research

Andreas Willi
(44 20) 7325 4835
andreas.p.willi@jpmorgan.com

Siemens

Siemens is emphasizing IGCC technology that could eventually be used with pre-combustion capture, and is not involved in post-combustion capture. Its biggest IGCC venture is a 1000 megawatt coal gasification plant in Spreetal, Germany, to be completed by 2009 at a cost of €1 billion. Siemens acquired the technology and engineering activities of Sustec Group in May 2006, enabling it to expand in coal gasification. Sustec has received several recent orders for large gasification plants, suggesting that its GSP entrained flow gasification technology is becoming viable.

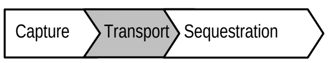
In the United States, Siemens is involved with a US Department of Energy program to develop and design a fuel-flexible advanced gas turbine as part of a capture-ready IGCC plant to be built starting in 2011-12. The company estimates the current cost of an IGCC plant at around €1,300 ($1,800) per kW, with fairly low 40% thermal efficiency even before the efficiency loss from carbon capture is factored in. The project aims to develop an IGCC plant that would cost no more than $1,000 per kW to build (in 2002 dollars), and that could capture 85-90% of carbon dioxide emissions without large efficiency losses.

Construction and Engineering Equity Research

Scott Levine
(1-212) 622-5609
scott.j.levine@jpmorgan.com

Washington Group

Washington Group, a US engineering and construction company with a large business in the power industry, recently formed an internal "skunkworks" within its power group to explore the ways in which CCS will impact its markets and to monitor the evolution of technology. The company has not said how it will participate from a technological standpoint, although we believe it is realistic to expect Washington Group to be involved in the engineering of clean-coal plants with a CCS component. The company expects a commercial CCS market to evolve over the next three to five years.



Transport

Oil Services & Equipment Equity Research

Kevin G. Pollard, CFA
(1-214) 965-3624
kevin.g.pollard@jpmorgan.com

Dresser-Rand

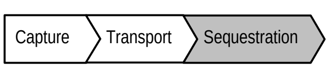
Dresser-Rand specializes in compressors for the energy industry. All potential methods of carbon capture and sequestration require compressing the gas prior to pipeline transportation, continued compression while in the pipeline, and compression during the process of underground injection, whether into an oilfield or another geologic structure. Increased use of CCS would be a positive for Dresser-Rand, which already makes a range of products specifically designed to handle CO_2. The company's leading competitors in compression equipment, General Electric and Siemens, often bundle compression with turbines and other products that Dresser-Rand does not make, which may put them in a better position to gain early sales. We expect Dresser-Rand to promote the greater efficiency of its compressors as a reason for purchasing compression separately.

Oil Services and Equipment Equity Research

Michael LaMotte
(1-214) 965-3623
michael.lamotte@jpmorgan.com

National Oilwell Varco

We think increased use of carbon sequestration would be positive for providers of oilfield equipment used to transport and inject CO_2. One company that would seem well positioned is National Oilwell Varco, which makes fiberglass pipe and thermoplastic coating for the transport of CO_2.



Sequestration

US Integrated Oils and Refiners Equity Research

Katherine Lucas, CFA
(1-212) 622-6451
katherine.a.lucas@jpmorgan.com

Chevron

As a major oil producer, Chevron has used CO_2 for enhanced oil recovery at its Rangely field in Colorado since 1986. Chevron transports CO_2 emitted from operations at a nearby natural gas processing facility to the oil field and injects it into the formation, improving oil recovery while simultaneously sequestering CO_2 that otherwise would be emitted into the atmosphere.

Carbon sequestration may also play a major role at the Gorgon liquefied natural gas project in Western Australia, in which Chevron has a 50% interest. Although Australia presently has no regulations concerning CO_2 emissions, Chevron sought to moderate opposition to its project by proposing to capture carbon dioxide brought to the surface along with natural gas and reinject it into a saline aquifer. In contrast to the Rangely project, sequestration at Gorgon would be undertaken entirely for environmental reasons and would not enhance hydrocarbon recovery. If Gorgon opens as planned early in the coming decade, it would be one of the largest carbon sequestration projects in the world. The project includes a significant subsurface monitoring component that could provide useful information for future sequestration efforts.

Chevron says its major research conclusion so far is that sequestration involves site-specific problems related to underground geology at particular locations. The company currently sees no appreciable earnings contribution from its carbon sequestration activities, observing that "we are in the early stages."

Independent Exploration and Production Equity Research

Joseph D. Allman, CFA
(1-713) 216-6503
joseph.d.allman@jpmorgan.com

Denbury Resources
Denbury is an independent oil producer that specializes in enhancing recovery from mature oil fields with CO_2 injection. The company controls the only known large natural source of CO_2 east of the Mississippi, as well as a CO_2 pipeline system centered on its CO_2 source. Under present conditions, CO_2 is actually a scarce resource in key oil production areas. We estimate that Denbury can deliver compressed CO_2 from its own source to its oil fields for $0.25 per thousand cubic feet, far below recent contract prices of $0.45-$1.00 per thousand cubic feet. This gives Denbury a significant cost advantage in oil production.

Most of the power plants near Denbury's key Mississippi oil fields are gas-fired, and even if coal plants begin to capture carbon at some point in the next decade, it may not be cost-effective to deliver it to Mississippi for sequestration. We think that this will preserve Denbury's business model for many years to come. Carbon dioxide from power plants is more likely to become available near Denbury's fields in Texas. As this occurs, we think the company's extensive experience injecting carbon dioxide for enhanced oil recovery will enable it to take advantage of the supplies, and also to build a cash-generating business from sequestration.

Electrical Equipment and Multi-Industry Equity Research

Steve Tusa
(1-212) 622-6623
stephen.tusa@jpmorgan.com

Emerson Electric
Emerson provided controls and process management for an EOR project at Weyburn, Saskatchewan, including systems to operate two compressors used to inject CO_2 into the field. The company expects to participate in carbon capture as part of its extensive activities in the power-generation sector, but notes that the business is not likely to become commercially viable for some time.

Oil Services and Equipment Equity Research

Michael LaMotte
(1-214) 965-3623
michael.lamotte@jpmorgan.com

Halliburton
Using depleted oilfields for CO_2 sequestration would require drilling of injection wells, and thus involve all oilfield service names. We think Halliburton would benefit from this potential market as it is already a leader in EOR project management and has a considerable suite of capabilities.

US Integrated Oils and Refiners Equity Research

Katherine Lucas, CFA
(1-212) 622-6451
katherine.a.lucas@jpmorgan.com

Occidental Petroleum
We believe that Occidental, like its peers, is interested in carbon sequestration primarily because of its ability to use captured CO_2 to enhance oil recovery in mature reservoirs. The ability to charge utilities for sequestering carbon would provide an incremental earnings contribution. Occidental is a world leader in the application of carbon-dioxide flood technology, using it extensively in the Permian Basin, which is

full of mature, long-exploited fields. Nearly half of Occidental's Permian production is from wells that use CO_2 flooding. Occidental also may be involved in the sequestration element of the proposed 500 megawatt hydrogen-fired power venture between BP and Edison Mission Energy in Carson, California. Technical studies are underway to determine which of Occidental's California oil fields would most benefit from flooding with the CO_2 to be captured at the Carson plant.

Schlumberger

Oil Services and Equipment Equity Research

Michael LaMotte
(1-214) 965-3623
michael.lamotte@jpmorgan.com

Among the oilfield service companies, Schlumberger seems to be most aggressive in developing the market for carbon sequestration. Schlumberger is part of an advanced project in Europe that is looking into the physics of mineralizing CO_2. This will be important when carbon dioxide is stored in some types of geologic structures, because the carbon dioxide can mix with water to create carbonic acid, which in turn can weaken the rock. Thus, technology needs to be developed that effectively seals the CO_2 inside a well or changes its physical properties to prevent a toxic environment. Schlumberger also is participating in Stanford University's Global Client and Energy Project, which is beginning to look into underground CO_2 sequestration capabilities. We believe Schlumberger, like Halliburton, has the subsurface skills and technologies to be a major played in the carbon sequestration market.

Analyst Certification:
The research analyst(s) denoted by an "AC" on the cover of this report certifies (or, where multiple research analysts are primarily responsible for this report, the research analyst denoted by an "AC" on the cover or within the document individually certifies, with respect to each security or issuer that the research analyst covers in this research) that: (1) all of the views expressed in this report accurately reflect his or her personal views about any and all of the subject securities or issuers; and (2) no part of any of the research analyst's compensation was, is, or will be directly or indirectly related to the specific recommendations or views expressed by the research analyst(s) in this report.

Important Disclosures

Important Disclosures for Equity Research Compendium Reports: Important disclosures, including price charts for all companies under coverage for at least one year, are available through the search function on JP Morgan's website https://mm.jpmorgan.com/disclosures/company or by calling this U.S. toll-free number (1-800-477-0406)

Explanation of Equity Research Ratings and Analyst(s) Coverage Universe:
JPMorgan uses the following rating system: **Overweight** [Over the next six to twelve months, we expect this stock will outperform the average total return of the stocks in the analyst's (or the analyst's team's) coverage universe.] **Neutral** [Over the next six to twelve months, we expect this stock will perform in line with the average total return of the stocks in the analyst's (or the analyst's team's) coverage universe.] **Underweight** [Over the next six to twelve months, we expect this stock will underperform the average total return of the stocks in the analyst's (or the analyst's team's) coverage universe.] The analyst or analyst's team's coverage universe is the sector and/or country shown on the cover of each publication. See below for the specific stocks in the certifying analyst(s) coverage universe.

JPMorgan Equity Research Ratings Distribution, as of March 30, 2007

	Overweight (buy)	**Neutral** (hold)	**Underweight** (sell)
JPM Global Equity Research Coverage	42%	41%	17%
IB clients*	49%	51%	38%
JPMSI Equity Research Coverage	38%	48%	14%
IB clients*	68%	64%	53%

*Percentage of investment banking clients in each rating category.
For purposes only of NASD/NYSE ratings distribution rules, our Overweight rating falls into a buy rating category; our Neutral rating falls into a hold rating category; and our Underweight rating falls into a sell rating category.

Valuation and Risks: Please see the most recent JPMorgan research report for an analysis of valuation methodology and risks on any securities recommended herein. Research is available at http://www.morganmarkets.com , or you can contact the analyst named on the front of this note or your JPMorgan representative.

Analysts' Compensation: The equity research analysts responsible for the preparation of this report receive compensation based upon various factors, including the quality and accuracy of research, client feedback, competitive factors, and overall firm revenues, which include revenues from, among other business units, Institutional Equities and Investment Banking.

Other Disclosures

Options related research: If the information contained herein regards options related research, such information is available only to persons who have received the proper option risk disclosure documents. For a copy of the Option Clearing Corporation's Characteristics and Risks of Standardized Options, please contact your JPMorgan Representative or visit the OCC's website at http://www.optionsclearing.com/publications/risks/riskstoc.pdf.

Legal Entities Disclosures
U.S.: JPMSI is a member of NYSE, NASD and SIPC. J.P. Morgan Futures Inc. is a member of the NFA. JPMorgan Chase Bank, N.A. is a member of FDIC and is authorized and regulated in the UK by the Financial Services Authority. **U.K.:** J.P. Morgan Securities Ltd. (JPMSL) is a member of the London Stock Exchange and is authorised and regulated by the Financial Services Authority. **South Africa:** J.P. Morgan Equities Limited is a member of the Johannesburg Securities Exchange and is regulated by the FSB. **Hong Kong:** J.P. Morgan Securities (Asia Pacific) Limited (CE number AAJ321) is regulated by the Hong Kong Monetary Authority and the Securities and Futures Commission in Hong Kong. **Korea:** J.P. Morgan Securities (Far East) Ltd, Seoul branch, is regulated by the Korea Financial Supervisory Service. **Australia:** J.P. Morgan Australia Limited (ABN 52 002 888 011/AFS Licence No: 238188) is regulated by ASIC and J.P. Morgan Securities Australia Limited (ABN 61 003 245 234/AFS Licence No: 238066) is a Market Participant with the ASX and regulated by ASIC. **Taiwan:** J.P.Morgan Securities (Taiwan) Limited is a participant of the Taiwan Stock Exchange (company-type) and regulated by the Taiwan Securities and Futures Commission. **India:**

J.P. Morgan India Private Limited is a member of the National Stock Exchange of India Limited and The Stock Exchange, Mumbai and is regulated by the Securities and Exchange Board of India. **Thailand:** JPMorgan Securities (Thailand) Limited is a member of the Stock Exchange of Thailand and is regulated by the Ministry of Finance and the Securities and Exchange Commission. **Indonesia:** PT J.P. Morgan Securities Indonesia is a member of the Jakarta Stock Exchange and Surabaya Stock Exchange and is regulated by the BAPEPAM. **Philippines:** J.P. Morgan Securities Philippines Inc. is a member of the Philippine Stock Exchange and is regulated by the Securities and Exchange Commission. **Brazil:** Banco J.P. Morgan S.A. is regulated by the Comissao de Valores Mobiliarios (CVM) and by the Central Bank of Brazil. **Japan:** This material is distributed in Japan by JPMorgan Securities Japan Co., Ltd., which is regulated by the Japan Financial Services Agency (FSA). **Singapore:** This material is issued and distributed in Singapore by J.P. Morgan Securities Singapore Private Limited (JPMSS) [mica (p) 069/09/2006 and Co. Reg. No.: 199405335R] which is a member of the Singapore Exchange Securities Trading Limited and is regulated by the Monetary Authority of Singapore (MAS) and/or JPMorgan Chase Bank, N.A., Singapore branch (JPMCB Singapore) which is regulated by the MAS. **Malaysia:** This material is issued and distributed in Malaysia by JPMorgan Securities (Malaysia) Sdn Bhd (18146-x) which is a Participating Organization of Bursa Malaysia Securities Bhd and is licensed as a dealer by the Securities Commission in Malaysia. **Pakistan:** J. P. Morgan Pakistan Broking (Pvt.) Ltd is a member of the Karachi Stock Exchange and regulated by the Securities and Exchange Commission of Pakistan.

Country and Region Specific Disclosures
U.K. and European Economic Area (EEA): Issued and approved for distribution in the U.K. and the EEA by JPMSL. Investment research issued by JPMSL has been prepared in accordance with JPMSL's Policies for Managing Conflicts of Interest in Connection with Investment Research which can be found at http://www.jpmorgan.com/pdfdoc/research/ConflictManagementPolicy.pdf. This report has been issued in the U.K. only to persons of a kind described in Article 19 (5), 38, 47 and 49 of the Financial Services and Markets Act 2000 (Financial Promotion) Order 2001 (all such persons being referred to as "relevant persons"). This document must not be acted on or relied on by persons who are not relevant persons. Any investment or investment activity to which this document relates is only available to relevant persons and will be engaged in only with relevant persons. In other EEA countries, the report has been issued to persons regarded as professional investors (or equivalent) in their home jurisdiction **Germany:** This material is distributed in Germany by J.P. Morgan Securities Ltd. Frankfurt Branch and JPMorgan Chase Bank, N.A., Frankfurt Branch who are regulated by the Bundesanstalt für Finanzdienstleistungsaufsicht. **Australia:** This material is issued and distributed by JPMSAL in Australia to "wholesale clients" only. JPMSAL does not issue or distribute this material to "retail clients." The recipient of this material must not distribute it to any third party or outside Australia without the prior written consent of JPMSAL. For the purposes of this paragraph the terms "wholesale client" and "retail client" have the meanings given to them in section 761G of the Corporations Act 2001. **Hong Kong:** The 1% ownership disclosure as of the previous month end satisfies the requirements under Paragraph 16.5(a) of the Hong Kong Code of Conduct for persons licensed by or registered with the Securities and Futures Commission. (For research published within the first ten days of the month, the disclosure may be based on the month end data from two months' prior.) J.P. Morgan Broking (Hong Kong) Limited is the liquidity provider for derivative warrants issued by J.P. Morgan International Derivatives Ltd and listed on The Stock Exchange of Hong Kong Limited. An updated list can be found on HKEx website: http://www.hkex.com.hk/prod/dw/Lp.htm. **Korea:** This report may have been edited or contributed to from time to time by affiliates of J.P. Morgan Securities (Far East) Ltd, Seoul branch. **Singapore:** JPMSI and/or its affiliates may have a holding in any of the securities discussed in this report; for securities where the holding is 1% or greater, the specific holding is disclosed in the Legal Disclosures section above. **India:** For private circulation only not for sale. **Pakistan:** For private circulation only not for sale. **New Zealand:** This material is issued and distributed by JPMSAL in New Zealand only to persons whose principal business is the investment of money or who, in the course of and for the purposes of their business, habitually invest money. JPMSAL does not issue or distribute this material to members of "the public" as determined in accordance with section 3 of the Securities Act 1978. The recipient of this material must not distribute it to any third party or outside New Zealand without the prior written consent of JPMSAL.

General: Additional information is available upon request. Information has been obtained from sources believed to be reliable but JPMorgan Chase & Co. or its affiliates and/or subsidiaries (collectively JPMorgan) do not warrant its completeness or accuracy except with respect to any disclosures relative to JPMSI and/or its affiliates and the analyst's involvement with the issuer that is the subject of the research. All pricing is as of the close of market for the securities discussed, unless otherwise stated. Opinions and estimates constitute our judgment as of the date of this material and are subject to change without notice. Past performance is not indicative of future results. This material is not intended as an offer or solicitation for the purchase or sale of any financial instrument. The opinions and recommendations herein do not take into account individual client circumstances, objectives, or needs and are not intended as recommendations of particular securities, financial instruments or strategies to particular clients. The recipient of this report must make its own independent decisions regarding any securities or financial instruments mentioned herein. JPMSI distributes in the U.S. research published by non-U.S. affiliates and accepts responsibility for its contents. Periodic updates may be provided on companies/industries based on company specific developments or announcements, market conditions or any other publicly available information. Clients should contact analysts and execute transactions through a JPMorgan subsidiary or affiliate in their home jurisdiction unless governing law permits otherwise.

Revised March 30, 2007.

Marc Levinson
(1-212) 622-5552
marc.levinson@jpmorgan.com