Carbon Capture and Storage
Capability and Experience
Zero Harm is our corporate vision for health, safety & the environment (HSE).

We are committed to our vision; it applies to all of our operations, at all times, in all locations, and at all levels of responsibility. We will actively work to align our expectations and behaviors with those required to achieve our vision through a dedication to continuous improvement.

The launch of our HSE framework, OneWay™, enables us to further align and consolidate our global systems and procedures and continue to work with our personnel to reinforce a culture that underpins our drive to achieve our corporate differentiator of industry leadership in the HSE performance.

“There is no task so important or so urgent in our business, or our customers’ businesses, that it overrides the need to work safely...”
John Grill, WorleyParsons CEO

Corporate Overview

WorleyParsons is a leading global provider of professional services to the resources & energy sectors, and the complex process industries.

We cover the full asset spectrum, both in size and lifecycle, from the creation of new assets, to services that sustain and improve operating assets.

Our business has been built by working closely with our customers through long term relationships, anticipating their needs and delivering inventive solutions through streamlined, proprietary project delivery systems. Strong growth continues to characterize our performance both through organic development and through strategic acquisition as we strive to provide tailored services wherever our customers need us.

EcoNomics™ is our range of services and technologies that profitably embed environmental, social and financial sustainability into project delivery, across the asset lifecycle. It is a seamless extension of our established project delivery capability in the key areas of Assessment, Efficiency and Treatment & Mitigation. We are committed to working with our customers to create solutions to meet the green challenge while staying in the black.

- Power
- Minerals & Metals
- Hydrocarbons
- Infrastructure

41 countries

140 offices

32,900 personnel
Carbon Capture and Storage

Working with global alliance partners, WorleyParsons provides comprehensive services for carbon capture and storage developments, from the earliest stages of evaluation to full-scale implementation and monitoring.

Carbon capture and storage (CCS) is just beginning to enter commercial-scale development. Clients at the forefront of these CCS applications need an engineering and project delivery partner that understands the technical, economic, and regulatory issues and opportunities relevant to their operations. The WorleyParsons CCS team offers clients innovative solutions backed by years of experience. Working through relationships with subsurface storage experts Schlumberger Carbon Services and carbon trading and legislation specialists Baker & McKenzie, we offer clients the comprehensive project management necessary for emerging CCS projects. Our CCS team offers services for every stage of carbon dioxide (CO₂) emissions management:

- Facility audits, sustainability plans, permitting, and emissions modeling and monitoring
- Cost-benefit analyses and feasibility studies
- Site screening and option evaluation studies
- Emissions treatment and control systems
- CO₂ capture, treatment, transport, and compression systems engineering and design
- Injection and sequestration modeling, injection well design, and storage monitoring
- Hydrogeologic impact, groundwater monitoring and modeling, and remediation
- Vapor mitigation, vapor monitoring and modeling, and fugitive gas assessments
- Environmental impact, ecological mitigation and monitoring, and risk assessments
- Procurement and Construction Management

WorleyParsons has been at the forefront of CCS, authoring some of the early reports on the subject for governmental agencies like the United States Department of Energy (DOE) and performing research for next generation power plants. Moreover, we have translated our technical knowledge gained on these research endeavors into successful real-world projects. As a leading professional services provider for resource and energy clients, WorleyParsons has worked with international clients on emissions control and carbon management. Each of the sectors we serve exposes us to relevant industry practices and innovations that support sustainable CCS applications.

WorleyParsons' experience covers all five phases of the asset lifecycle. In each one of these phases we understand the critical issues and apply our specialist business lines, Select, Deliver and Improve to enable our customers to achieve their business objectives.

Our phased approach enables consistent project delivery worldwide and WorleyParsons' project systems are fully aligned to this process.
Capability Overview

CCS Program Management
WorleyParsons brings together a highly-qualified team of process, air quality, pipeline, geology, and environmental specialists to deliver comprehensive CCS services. Our world-leading engineering, procurement, and construction management (EPCM) capability provides overall support of CCS developments. In this way, WorleyParsons continues its vision of being the preferred professional services firm for resource and energy customers.

CO₂ Separation and Capture
With decades of experience in both CO₂ separation for the hydrocarbons processing sector and air quality control for the power sector, WorleyParsons has extensive expertise in CO₂ process engineering. WorleyParsons offers emissions capture solutions for post combustion CO₂ sources, pre-combustion and oxy-fuel sources, and CO₂ separation from natural gas streams and other industrial sources.

CO₂ Compression and Treatment
Drawing on our vast process engineering background in the natural gas industry, WorleyParsons has developed expertise in CO₂ compression and treatment (including dehydration). This is a crucial step for transmission and storage, given the volatility of CO₂ and the distance it must travel for sequestration.

CO₂ Pipelines
Our CO₂ transmission capability is backed by our global reputation of excellence in pipelines. WorleyParsons designed CO₂ pipelines for some of the world’s largest CCS projects, including the Encana Weyburn Unit CO₂ enhanced oil recovery (EOR) project and the Enbridge Alberta Saline Aquifer Project. These projects, coupled with our global pipeline capability, has made WorleyParsons one of the premiere CO₂ transmission specialists.

Environmental Compliance
WorleyParsons is a world leader in environmental programs including groundwater, subsurface, and atmospheric monitoring systems. With over 750 environmental and geosciences specialists, WorleyParsons helps clients work through regulatory issues involving carbon storage. Our environmental staff works with engineers to resolve risks to the environment posed by CO₂ transmission and sequestration.
CCS Program Management

As a leading project delivery firm serving the hydrocarbons, power, mining, and infrastructure sectors, WorleyParsons offers clients practical solutions for CCS developments.

Our capabilities extend to all phases of CCS program implementation. By providing life cycle services, we provide our clients with confidence in the long-term sustainability of their assets.

WorleyParsons works with customers from the earliest stages of CCS project development to ensure that the optimal solution is selected. We conduct pre-feasibility screenings of available CCS options to identify opportunities and risks. Our EcoNomics™ services provide identification and quantification of both project-based and external risks of the CCS program. Our EcoNomics™ experts then develop mitigation strategies that reduce program risks to acceptable thresholds as efficiently as possible. These evaluation steps help to pinpoint the CCS option that offers the maximum return for our customers.

Once a preferred solution is selected, our firm works with global alliance partners such as Schlumberger Carbon Services to conduct detailed site characterization. Characterization includes collection of site-specific data like test well drilling and logging, 2-D and 3-D seismic profiling, and dynamic reservoir modeling. WorleyParsons uses this data to optimize the reservoir model for CO₂ injection, incorporating specifications for the number and locations of injection wells, depths, and rates. This model then guides the engineering design.

Using the data collected, WorleyParsons provides engineering design, procurement, and construction management of pipelines and facilities for capturing and handling CO₂ emissions. Through our alliance with Schlumberger Carbon Services, we also provide drilling and completion of injection wells.

During the operating life of the CO₂-producing plant, we provide ongoing engineering support to sustain effective operations. WorleyParsons and our strategic partners employ a variety of methods to verify the amount of CO₂ captured and injected during plant operations, from process instrumentation at the plant to time-series 3-D seismic surveys at the reservoir. We will also update reservoir models periodically to validate storage performance. Monitoring of CO₂ storage helps verify sequestration and allow detection of any losses, protecting shallow subsurface resources like potable groundwater.

When plants reach the end of their useful lives and cease CO₂ injection, WorleyParsons continues to monitor CO₂ sequestration. We monitor groundwater, soil gas, and other environmental receptors and conduct 3-D seismic surveys to safeguard against leakage of CO₂.

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**Project:** Mountaineer Plant Commercial Scale Carbon Capture and Storage (CCS) Project  
**Customer:** American Electric Power  
**Phases:**  

WorleyParsons is the engineer for Phase I - project definition of the four-phased Commercial Scale Carbon Capture and Storage (CCS) Project. The project is one of the US Department of Energy’s (DOE) Clean Coal Power Initiatives demonstrating commercial-scale carbon dioxide capture fully integrated with CO₂ compression and deep geologic storage. Successful demonstration of the carbon capture process coupled with sequestration will demonstrate the viability of sequestration in deep saline reservoirs. It will also reduce the risk associated with commercial deployment of CCS technology by reducing CO₂ capture costs compared to conventional post-combustion capture systems. The technology could be applied to many additional gigawatts of coal-based electric capacity in the United States and throughout the world.
Project: ENDESA CCS project  
Customer: Endesa, S.A  
Phases: IDENTIFY EVALUATE DEFINE EXECUTE Operate  
Spain

WorleyParsons continues its leadership in carbon management through our award of multiple contracts for ENDESA to help develop their EU funded CCS project in Spain. Two of the awards are transport studies involving the dynamic analysis and the dispersion model of a proposed approximately 130 km CO₂ pipeline. The third contract, awarded in collaboration with Schlumberger, is a PMC contract to manage the characterization and design of a CO₂ storage facility in Northern Spain. The ENDESA CCS project is one of the six European Union funded demonstration projects, and the plan for this project is to construct a 320 MW CFB plant with an Oxyfuel Capture system and a transport pipeline.

Project: Strategic Carbon Management Plan  
Customer: Confidential  
Phases: IDENTIFY EVALUATE DEFINE EXECUTE Operate  
United States

WorleyParsons was retained to develop a carbon management plan for a new coal power plant and three existing facilities in the Midwest. Integrating our power engineering, environmental, and EcoNomics™ capabilities, the WorleyParsons team helped determine their best options for managing CO₂ emissions. Options considered included CO₂-EOR, underground sequestration in saline formations, and trading CO₂ in commercial markets. WorleyParsons also provided analysis of geological and hydrogeological settings of possible sites for CCS. As part of the evaluation, WorleyParsons worked with Baker & McKenzie to provide our customer with guidance on pending US legislation.

Project: Large Scale Integrated CCS Network  
Customer: Commonwealth of Pennsylvania  
Phases: IDENTIFY EVALUATE DEFINE EXECUTE Operate  
United States

WorleyParsons led a commercial/government committee to define three fully integrated, global, large-scale, CCS projects in the State of Victoria, Australia and the Commonwealth of Pennsylvania. The focus was to develop a strategic technical and business plan, encompassing quantitative and qualitative metrics, for a large-scale integrated CCS network from multiple utility and industrial operations. The projects optimized the deployment of CCS on a global basis. Operational at volumes in excess of 20 million tons of CO₂ per year between 2015-2025 are expected. In addition, the projects comprise multiple CO₂ capture facilities, shared CO₂ transportation, and storage infrastructure to meet both near and long-term needs.

Project: Strategic Analysis of the Global Status of Carbon Capture and Storage Projects  
Customer: Global Carbon Capture and Storage Institute  
Phases: IDENTIFY EVALUATE DEFINE EXECUTE Operate  
Australia

WorleyParsons led a consortium supported by Schlumberger, EPRI, and Baker & McKenzie to analyze the global status of CCS projects. This project covered the status of demonstration projects; the costs of CCS; and the impact of the global financial crisis, policy and regulatory frameworks, research and development efforts, and the commercial and non-commercial gaps to the global deployment of CCS.
CO₂ Separation and Capture

WorleyParsons has amassed decades of CO₂ separation and capture experience gained from the upstream oil and gas sector.

This experience helps us to tailor our solutions to meet the challenges of both pre-combustion and post-combustion CO₂ sources. WorleyParsons separation and capture services include selection of CO₂ capture technology, equipment specification and procurement, front end engineering design (FEED), and EPCM.

WorleyParsons works with commercial licensors of solvent-based processes such as UOP, Lurgi, Shell, BASF, Linde, Dow, ExxonMobil, Mitsubishi and Union Carbide to help identify the best-suited processes for a particular application. We consider separation technologies appropriate for the source CO₂ stream including a range of proprietary amine-based absorption processes from world-leading suppliers for post-combustion CO₂ capture. A more extensive selection of absorbent amines and physical solvent such as glycols or hybrid solvents are considered for pre-combustion or oxy-fuel CO₂ capture.

Solvent-based separation technologies are typically used for CO₂ removal from natural gas streams or other industrial sources. Solvents can be tailored for sequential removal of hydrogen sulfide (H₂S) and CO₂. Emerging technologies for CO₂ separation or capture include chilled ammonia absorption (notably for post-combustion capture), adsorption using molecular sieves or activated carbons, polymeric gas separation membranes and solid sorbents such as reactive metal oxides. Other emerging variations for pre-combustion CO₂ capture include sorption enhanced reaction and membrane reactors.

Two key design factors in optimum solvent selection are minimizing energy requirements for regeneration and maximizing solvent life. In these areas, WorleyParsons’ experience provides a value-added return to a CO₂ capture system design. In addition, CO₂ capture can be integrated to use waste heat from low-pressure steam generation to minimize regeneration energy use.

Project: FutureGen 2.0
Customer: Babcock & Wilcox Power Generation Group, Inc. (B&B PGG)
Phases: United States

WorleyParsons was chosen by Babcock & Wilcox Power Generation Group, Inc. (B&W PGG) to provide engineering services and cost estimating support for the Boiler and Gas Quality Control System islands during Phase 1 of the project. The USDOE-supported FutureGen 2.0 project is being demonstrated at Ameren’s Meredosia Power Plant in Morgan County, Illinois. The work for engineering services and related deliverables includes, among other things, coal handling, ash handling, interconnecting piping, electrical, controls, buildings/enclosures, architectural, fire protection, foundations, and civil work.
CO₂ Compression and Treatment

WorleyParsons applies worldwide gas compression to the unique requirements of CO₂ compression and dehydration.

Compression and treatment (including dehydration) of CO₂ is a fundamental component of any CCS program. After capture, CO₂ must be compressed to allow for treatment and transport. This may require multiple stages of compression.

CO₂ is a highly reactive acid gas that readily forms carbonic acid when exposed to even minute amounts of liquid water. Consequently, dehydration is a key step in preparing CO₂ for pipelining. Typically, after the third stage of a four-stage compression process the gas is dehydrated using a glycol-based solution such as tri-ethylene glycol (TEG). WorleyParsons’ experience in dehydration spans a very broad range of facilities using commercial glycols.

Typical pipeline specifications require CO₂ to be free of water and other impurities, notably oxygen, nitrogen, and argon. Generally, compression at the source must be high enough so that booster compression is not necessary en route to the receiving terminal, which can be as much as hundreds of kilometers from the source.

WorleyParsons offers compression and dehydration services that include selection, specification and procurement of compression and dehydration equipment, FEED, and detailed EPCM.

Project: Wayne Oil and Gas Development
Customer: PanCanadian Petroleum Ltd.
Phases: IDENTIFY, EVALUATE, DEFINE, EXECUTE, OPERATE

This project successfully emphasized operational safety and facility flexibility as its primary design goals.

WorleyParsons performed design, procurement, and construction management of the well sites, flow lines, satellite, battery, gas sweetening, hydrocarbon dewpoint control, LPG mix recovery, refrigeration, acid gas injection, and sales gas compression facilities of a sour oil field. The total production rate from the wells was 6000 bpd of oil with a GOR of 100 and 4 MMSCFD of gas. The facilities included an acid gas compression system which reinjected 25% H₂S / 75% CO₂ gas into a disposal well. The acid gas was flared initially and then reinjected into a formation. The acid gas disposal and compression system included a 300 hp compressor which reinjected the H₂S / CO₂ gas for disposal.
WorleyParsons is a pioneer in CO₂ transmission, engineering pipelines for some of the world’s largest CCS developments.

WorleyParsons brings world-class pipeline capability to meet the needs of CO₂ transmission for CCS programs. Having engineered over 50,000 km of onshore pipelines, including major CO₂ pipelines, WorleyParsons offers clients the skill set for compressed gas transmission. Our CO₂ pipeline services include siting studies, FEED, detailed design, procurement, and construction management.

The design basis for CO₂ pipelines must incorporate a number of factors such as transmission distances, volumes, and delivery pressures. Material selection for CO₂ pipelines is critical, and must consider advanced pipe coatings, crack propagation characteristics and corrosivity. WorleyParsons engineers appreciate the importance of proper equipment selection that adhere to applicable constructability factors such as welding precautions and use of crack arrestors in the long term maintenance and performance of CO₂ pipelines.

Automation of CO₂ pipeline controls and monitoring is a key component of WorleyParsons design. SCADA systems, including fiber-optic and other advanced communication systems, are employed to insure reliable real-time process and performance information.

**Project: Weyburn Field CO₂-EOR Program**
**Customer: Encana Resources**
**Phases:** IDENTIFY > EVALUATE > DEFINE > EXECUTE > OPERATE

Weyburn is one of the world’s largest CO₂ injection, recovery, and storage projects.

WorleyParsons provided professional services for the Weyburn, Saskatchewan oil field, including complete CO₂-EOR engineering support. CO₂ is supplied by a 400 km pipeline from the Dakota Gasification Great Plains Synfuels Plant. The CO₂ is then distributed to numerous injection wells. CO₂ in the produced fluids is separated and re-circulated for injection; however, a significant portion of the CO₂ remains within the target formation, providing the added benefit of carbon storage. Our services covered all phases of field development and EOR program design and implementation, including scoping, planning, cost estimating, scheduling, FEED and detailed design, permitting, construction management, and field operations.

**Project: Geo-Sequestration Compression and Pipeline Study**
**Customer: Macquarie Generation**
**Phases:** IDENTIFY > EVALUATE > DEFINE > EXECUTE > OPERATE

WorleyParsons completed pre-FEED conceptual engineering of a 623 km CO₂ pipeline in New South Wales (NSW). Delta Electricity, Macquarie Generation, and Eraring Energy contracted WorleyParsons to determine the costs and viability of piping CO₂ released from power generation to saline aquifers, depleted oil and gas reservoirs, and unmineable coal seams in the Darling Basin, NSW. The scope was to study and cost a 36” pipeline and compression system. Three separate extraction technologies were considered with varying degrees of water content. The work included route selection, process modeling, materials and corrosion studies, conceptual design of the pipeline, compressor / pumping stations, valve stations, and pigging facilities as well as a CAPEX estimate.
Environmental Compliance

WorleyParsons' experience in environmental monitoring and compliance helps customers navigate the process of permitting CCS facilities and operations.

Environmental permitting for CCS projects is in a state of flux, requiring intimate knowledge of both the applicable local regulations and the permitting process. While many governments of petroleum-producing states have existing regulatory frameworks for CO₂-EOR, very few have established guidelines for CO₂ geosequestration. The result is a regulatory process that is often complex and inconsistent across jurisdictions.

WorleyParsons has over 600 environmental staff worldwide to provide permitting support throughout the CCS program. Our geologists, geochemists, and air quality specialists have experience negotiating with regulatory agencies in many countries and territories and are familiar with the obstacles of CO₂ management. We also draw on our global alliance partner Baker & McKenzie to help our customers understand legal uncertainties of CCS.

In addition, many liability questions around CCS have yet to be resolved. In most jurisdictions, ownership of underground storage pore space, the rights of overlying landowners, and the long-term liability for CO₂ storage are not defined. Through the EcoNomics™ risk assessment process, WorleyParsons assembles an interdisciplinary team that identifies risks to project success, the community, and the environment. Once all internal and external risks are identified, we apply our sophisticated financial modeling tools to develop cost-effective mitigation measures to reduce potential liability.

WorleyParsons’ environmental staff monitor CO₂ storage to both verify performance and to protect against environmental damage. Leaking injection wells, abandoned wells, faults, fractures, or ineffective confining layers or cap-rock can all lead to unplanned near-surface releases of injected CO₂. Leakage can degrade potable groundwater resources and pose a risk to human health and ecological habitats. WorleyParsons has decades of environmental monitoring experience and global resources to manage monitoring programs in areas where CO₂ is likely to be stored.

Project: **FutureGen Site Evaluation and Selection**  
**Customer:** Confidential  
**Phases:**  
- Define  
- Execute  
- Operate

**United States**

**FutureGen will be the first near-zero-pollution power plant in the United States.**

WorleyParsons evaluated fourteen potential sites to determine the best locations for siting the federally proposed 275 MW FutureGen Plant. Our team included geologists with specialized expertise to evaluate the characteristics of deep geologic formations to permanently capture and store CO₂. Key work completed during this phase of the project included analysis of options for acquiring land, infrastructure development requirements, sequestration target formation and plume definition, and environmental characterization.
Our Vision

WorleyParsons will be the preferred global provider of technical, project and operational support services to our customers, using the distinctive WorleyParsons’ culture to create value for them and prosperity for our people.

Leadership
Committed, empowered and rewarded people
EcoNomics™ – Delivering profitable sustainability
Integrity in all aspects of business
Energy and excitement
Minimum bureaucracy

Agility
Smallest assignment to world scale developments
Local capability with global leverage
Responsive to customer preferences
Optimum solutions customized to needs

Relationships
Rapport with all stakeholders
Open and respectful
Collaborative approach to business

Performance
Zero harm
Results for our customers and other stakeholders
World-class resources, capability and experience
For further information about our global capability email: carbonstorage@worleyparsons.com

www.worleyparsons.com