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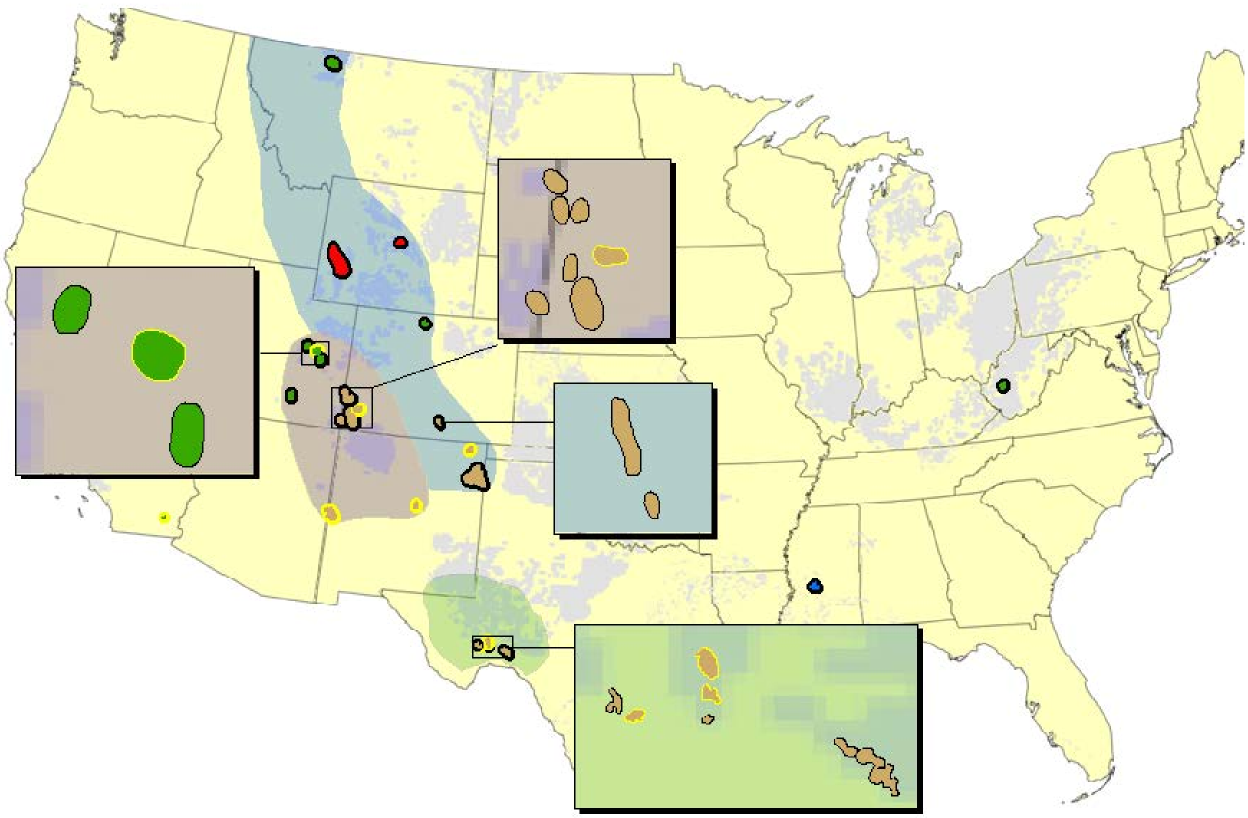

Subsurface Sources of CO_2 in the Contiguous United States

Volume 1: Discovered Reservoirs

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Working Paper

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Exhibits

Acronyms and Abbreviations

3P	Proven, probable and possible
AF	Access factor
AU	Assessment Unit
Bcf	Billion cubic feet
Bcfd	Billion cubic feet per day
Bgi	Formation volume factor
BLM	Bureau of Land Management
BPLB	Big Piney-LaBarge field
CAPEX	Capital expense
CO2	Carbon dioxide
CREAM	CO_2 Resources Evaluation Analytical Model
DOE	Department of Energy
EBT	Earnings before taxes
EIA	Energy Information Administration
EOR	Enhanced oil recovery
EPA	Environmental Protection Agency
ERR	Economically recoverable resources
ESPA	Energy Sector Planning and Analysis
ETSAP	Energy Technology Systems Analysis Programme
EUR	Estimated ultimate recovery
GIIP	Gas-initially-in-place
GIS	Geographical Information System
IEA	International Energy Agency
INGAA	Interstate Natural Gas Association of America
Ma	Millions of years ago
Mcf	Thousand cubic feet
mD	Millidarcy
MGS	Montana Geological Society
MMcf	Million cubic feet
MMcfd	Million cubic feet per day
NG_{EUR_Tier}	Natural gas EUR for a specific tier
NETL	National Energy Technology Laboratory
NPV	Net present value
OPEX	Operating expense
ppm	Parts per million
psi	Pounds per square inch
rcf	Reservoir cubic feet
RF	Recovery factor
scf	Standard cubic feet
SEC	Securities and Exchange Commission
SMU	Southern Methodist University
T	Tier
TI	Tier (inclusive)
Tcf	Trillion cubic feet
TRR	Technically recoverable resources
UGS	Utah Geological Survey
U.S.	United States
USGS	U.S. Geological Survey
VBA	Visual Basic for Applications

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Executive Summary

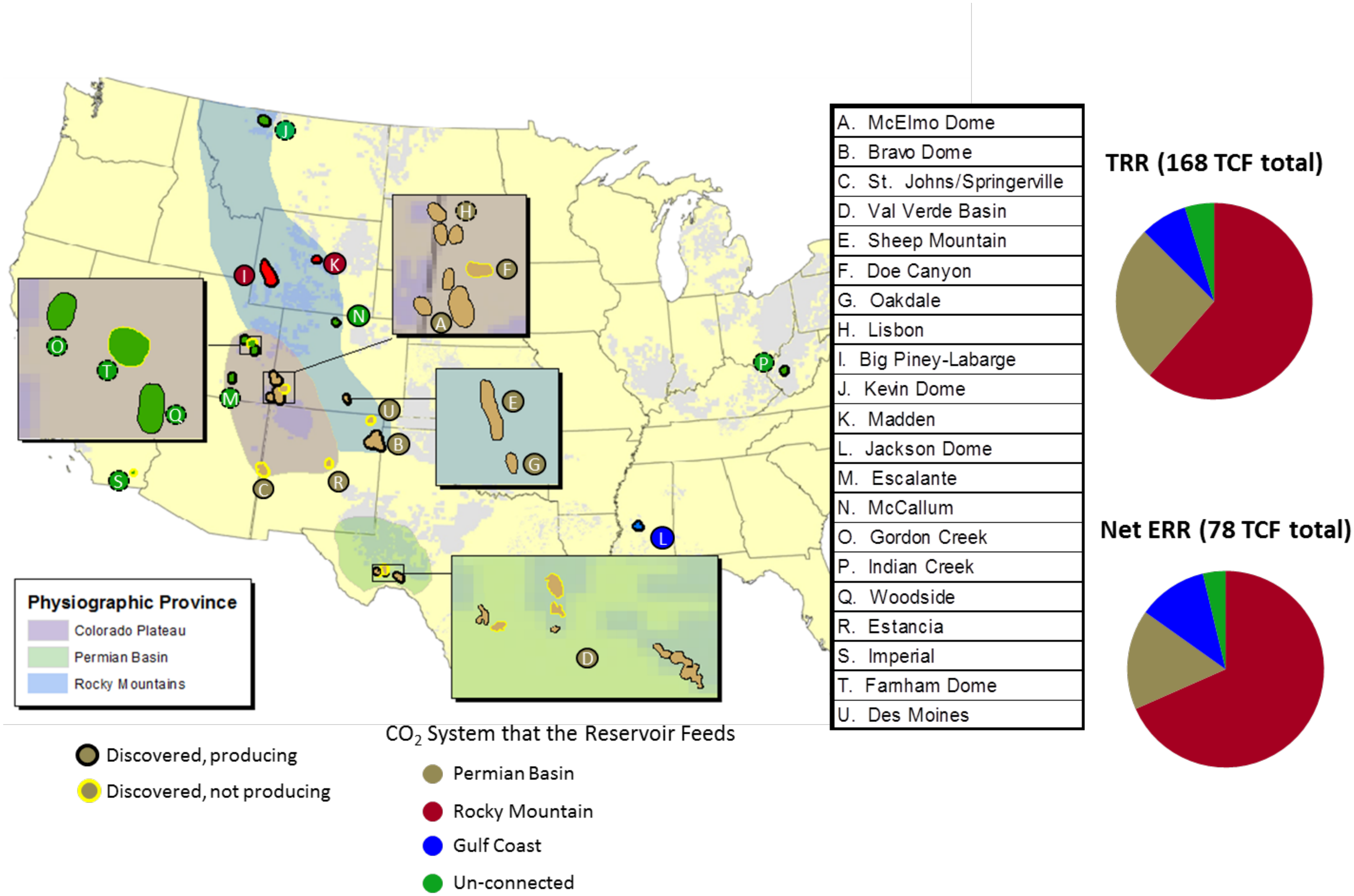
The production of carbon dioxide (CO_2) from subsurface sources in the United States has grown from 0.6 Tcf per year in 2000 to 1.1 Tcf per year in 2013. Approximately 97 percent of the CO_2 is used for enhanced oil recovery (EOR). In response to continued and growing demand in this sector, production has recently been initiated at Doe Canyon and, with the exception of Sheep Mountain which is in decline, all established CO_2 production operations are undergoing drilling programs or expansions of gas processing facilities to increase the rate of production. Production from subsurface sources of CO_2 is forecast to reach 1.5 Tcf/yr by 2018. (Murrell, 2013)

This study compiles information about subsurface carbon dioxide (CO_2) accumulations in the continental United States and estimates the recoverable resource. Twenty-one CO_2 fields in the contiguous states contain an estimated 311 Tcf of CO_2 gas-initially-in-place (GIIP). Of that, 168 Tcf (54 percent) is estimated to be accessible and technically recoverable. The estimated economically recoverable resource (ERR) is 96.4 Tcf, based on a CO_2 price of 1.06 $/mcf ($20/tonne) at the field gate. Cumulative production to date is 18.9 Tcf, leaving 77.5 Tcf remaining or net ERR. The Big Piney-LaBarge field in Wyoming contains an estimated net ERR of 52 Tcf, 67 percent of the total for the United States. The remaining ERR in reservoirs that feed into the Permian Basin and Gulf Coast is on the order of 10-20 years of supply. The technically recoverable resource (TRR) in the Permian Basin and Gulf Coast is on the order of 30 years of supply. The ERR at LaBarge contains an estimated 260 Bcf of helium, while the ERR at St Johns/Springerville may contain 25 Bcf of helium.

Exhibit ES-1 shows the location of the twenty-one CO_2 fields. Three adjoining states, Colorado, Wyoming and Utah, account for 71 percent of the GIIP. Pipeline infrastructure connects many of the CO_2 fields in Colorado and Utah to the oil fields in the Permian basin. Newly built pipelines are enabling increased utilization of the CO_2 resources in Wyoming and Mississippi.

Data was gathered from technical journals and other sources to enable the volumetric calculation for GIIP. The volumetric calculation was tailored to the resolution of the data available for each CO_2 field. For Big Piney LaBarge, we employed GIS methods to integrate data from maps showing structural depth and CO_2 concentration contours and identified 48 polygons with unique combinations of these attributes. We report Val Verde as one source, but technically it is seven distinct fields producing from seven distinct reservoirs, two in the upper plate of the Marathon Thrust and five in the Marathon subthrust. Escalante comprises five vertically stacked reservoirs within the same field. Similarly, Kevin and Gordon Creek are both single fields with two vertically-stacked reservoirs. In the case of stacked reservoirs, wells were modeled with multiple completions. The other sixteen fields are modeled as horizontal disks with a single-point estimate for depth, porosity, etc.

Exhibit ES-1 Subsurface sources of CO_2 in the U.S.



Two degradations were applied to GIIP to estimate TRR. First, reservoir maps were overlain with GIS shape files for national parks, historical sites, wetlands and other areas where drilling is restricted, then the percent of accessible reservoir area was estimated. Second, the percent of accessible GIIP that could be technically produced was estimated. An expected recovery factor of 70 percent GIIP was used as a baseline, as is typical for natural gas and confirmed by studies of CO_2 reservoirs previously conducted by the authors. This baseline recovery factor was adjusted up or down for each reservoir based on its geology.

A project cash flow model was exercised to make the ERR determinations for each field. The revenues from produced CO_2 and other by-products and contaminants (helium, methane, nitrogen, etc.) were matched against the cost of drilling wells and also the cost of processing and compressing the produced gas. A 12 percent discount rate (after tax) was used.

The economics of the subsurface sources is primarily influenced by the estimated ultimate recovery (EUR) per well, which in our characterization is a function of the density of the resource (Bcf CO_2 per acre). Thicker pay and higher porosity improve the density, all else equal. If the reservoir temperature and pressure are such that CO_2 exists in the formation as a supercritical fluid (as opposed to a gas) the density is significantly higher. CO_2 is supercritical in all of the formations except Bravo and St. Johns. Escalante and Kevin Dome are within the supercritical region but are borderline. The best reservoirs (top third of GIIP) have a resource density of 0.30 – 0.35 BscfCO_2/acre. The middle third of GIIP has a density between 0.15 and 0.3 Bscf CO_2/acre.

The economic analysis was conducted by field or by individual reservoir within a larger field where data permitted (i.e., Big Piney-LaBarge, Val Verde, Escalante, Kevin Dome and Gordon Creek). We further divided each field/reservoir into four productivity tiers. This is based on experience in the oil and gas industry with "sweet spots." The underlying assumption is that developers will be able to find the sweet spots and develop the tiers sequentially. The relative values for EUR were drawn from data for unconventional oil and gas reservoirs and are shown in Exhibit ES-2. For example, the top tier represents wells in the top 10 percent of the reservoir, which provide 22 percent of the total expected ultimate recovery. The well EUR adjustment factor for each tier equals the percent total EUR divided by the portion of the reservoir in the tier.

Exhibit ES-2 Factors applied to model tiers of well productivity

Tier	Portion of reservoir	% of total EUR	Well EUR adjustment factor
1^{st}	10	22	2.20
2^{nd}	20	31	1.55
3^{rd}	30	31	1.03
4^{th}	40	16	0.41

Well spacing of 640 acres is assumed for all fields except St. Johns which is 320 acres. For each reservoir a 30-year production profile is derived from the P_T and assuming a decline rate of 6 percent per year.

The cash flow model assumes an average cost of $630/ft for each production well (U.S. DOE Energy Information Administration) with some regional adjustments and a 15 percent dry hole burden. The compressor cost factor is 0.237 $/MMcf/delta psi (draft NETL report). The required pressure gain is a function of the well head pressure (calculated from the downhole pressure and an estimated well bore gradient, gathering line losses and the estimated pressure drop across gas processing equipment).

The assumed selling price for CO_2 is 1.06 $/Mcf ($20/tonne) at pipeline purity and pressure at the field gate. If nitrogen in the produced gas is above 4 percent we assume it must be separated out, which represents a significant expense. We assume that hydrogen sulfide (H_2S), methane and light hydrocarbons can be separated and sold. If helium is present at a concentration above 0.3 vol% (Big Piney LaBarge and St. Johns) we assume it can be captured and sold. We use 125 $/Mscf as the long-term price for helium.

Exhibit ES-3 presents a one-page overview of the analysis. For each CO_2 field the production rate during 2013 is shown, as are key parameters that support the GIIP and TRR calculations, the latter of which is derived from the GIIP and the access and technical recovery degradation factors. The exhibit also shows the average gas composition at each field. For fields that were divided into reservoirs or polygons, Exhibit ES-3 presents weighted average values for the field overall. Big Piney LaBarge is divided into three areas, basinal, foreland and highland based on topographic expression, to represent differences in accessibility and drill depth. The overall observation from Exhibit ES-3 is that each CO_2 field offers a unique combination of size, resource density, accessibility and produced gas composition that affect the economics of production.

This analysis was conducted without consideration of markets or capital investment requirements beyond the field lease line at each of the CO_2 fields. The ERR calculation would be different if one took into consideration, for example, existing CO_2 compression or pipeline transport infrastructure at Val Verde. In that way, the ERR analysis is designed to offer a comparison of the quality of the different fields/reservoirs. Exhibit ES-3 shows both the “gross ERR” and the “net ERR.” The gross ERR for a field equals the sum of the potential production from all the reservoir-tiers that clear economic criteria. The net ERR equals the gross ERR minus the cumulative amount of CO_2 already produced from that field.

We exercised the cash flow model to estimate the sensitivity of the results to the assumed price of CO_2. Decreasing the price 25 percent to 0.8 $/Mscf (15 $/mtCO_2$) causes a 73 percent reduction in net ERR, from 77.5 Tcf to 21 Tcf. Increasing the CO_2 price 25 percent to 1.32 $/Mscf (25 $/mtCO_2$) increases the ERR 35 percent to 105 Tcf.

There are other areas of uncertainty in the estimates for GIIP, TRR and ERR. For example, we were not able to find unique maps for Bravo or Jackson Dome. The cost and performance of helium capture systems and other gas processing operations are held as proprietary. We do not have production well models or systems analyses of gas processing systems to predict CO_2 compressor inlet pressure at each field. The TRR recovery factors (%GIIP recoverable) are based on literature research and the expertise of the authors rather than measurements of reservoir permeability. Well spacing is generically applied. NETL is undertaking efforts to address these areas of uncertainty and others and plans to publish an updated version of its working paper.

Another source of uncertainty in the resource estimate is the potential for discovery of new CO_2 field(s). Accordingly, NETL is undertaking a parallel effort to identify and assess leads for undiscovered CO_2 resources in the United States. That study looks more closely at the geology and tectonics of the discovered CO_2 reservoirs and the sequence of trap formation and CO_2 emplacement. The study then explores five areas for possible undiscovered leads within the geologic trends where the discovered reservoirs are found. A companion NETL document contains the analysis of undiscovered CO_2 resources.

Exhibit ES-3 Subsurface sources of CO_2 in the U.S.

CO_2 EOR System	Structure or Field	State	2013 Production MMscfd	Rock type	Depth	Area	Pay	Por	FVF	Rec	Access	Gas Components, volume %					Resource Estimates, Tcf				
					000 ft	000 acres	ft	%	rcf/ (000 scf)	%	%	CO_2	CH_4	N_2	He	H_2S	GIIP	TRR	Gross ERR	Cumm Prdn	Net ERR
Permian Basin	McElmo	CO, UT	1,135	LS	8.0	202	95	12	2.6	70	65	98	0	2	0.07	--	30	14	12	7.2	4.4
	St. Johns	NM, AZ	--	SS	1.5	220	75	15	9.0	70	80	93	--	4	0.60	--	8.9	5.0	4.3	0.09	4.2
	Bravo Dome	NM	405	SS	2.6	700	125	20	16.0	65	90	97	--	--	0.02	--	23	14	5.4	2.9	2.5
	Doe Canyon	CO	105	LS	9.0	82	60	10	3.2	70	75	95	--	--	--	--	5.1	2.7	1.1	0.09	1.0
	Val Verde	TX	165	Dol	14	70	650	4	3.5	70	95	42	58	--	0.01	--	7.3	4.9	1.6	1.5	0.1
	Oakdale	CO	--	SS	6.0	3	250	19	3.5	65	80	72	28	--	0.03	--	1.2	0.6	0.5	0.01	0.5
	Sheep	CO	45	SS	5.0	12	145	20	3.9	65	80	97	1	--	0.03	--	3.1	1.6	1.4	1.3	0.1
	Lisbon	UT	--	LS	10	3	75	12	3.8	70	85	90	--	--	--	--	0.2	0.1	--	--	--
															Subtotal		79	43	26	13	13
Rocky Mountain	BPLB Basinal	WY	108	SS, dol	16	138	275	9	2.8	70	85	85	9	3	0.50	2.4	113	67	45	1.5	43.2
	BPLB Foreland	WY	107	SS, dol	16	125	275	9	3.2	70	80	74	15	6	0.50	4.2	30	17	7.2	1.5	5.7
	BPLB Highland	WY	--	SS, dol	18	388	275	9	3.0	70	30	81	11	4	0.50	3.0	30	6.4	3.2	--	3.2
	Madden	WY	35	dol	24	80	175	15	3.8	70	95	20	67	--	--	12	3.8	2.5	--	0.08	--
															Subtotal		177	93	55	3.1	52
Gulf Coast	Jackson Dome	MS	1,025	LS	16	90	185	13	2.8	70	95	90	5	--	0.00	5.0	24	16	11	1.8	8.9
Not Connected to a System	Escalante	UT	--	SS, LS	2.3	37	172	7	9.1	55	45	95	--	4	0.01	--	10	2.5	1.7	0.00	1.7
	Kevin Dome	MT	--	LS	3.6	261	67	9	5.3	75	95	88	--	12	--	--	14	10	1.1	--	1.1
	McCallum	CO	1.0	SS	5.5	15	100	20	3.5	70	90	92	--	--	0.11	--	2.8	1.8	1.5	0.87	0.6
	Gordon Creek	UT	--	LS	13	8	135	9	2.4	65	90	99	0	0	-	--	1.7	1.0	0.6	0.00	0.6
	Indian Creek	WV	0.1	SS	6.7	18	10	10	3.7	70	95	66	30	4	0.15	--	0.1	0.1	--	0.02	--
	Woodside	UT	--	SS	3.5	13	45	9	5.2	60	90	32	--	62	--	--	0.1	0.1	--	--	--
															Subtotal		29	15.4	4.9	0.90	4.1
																Total*	311	168	96.4	18.9	77.5

Conversion factor: 52.9 million metric tons CO_2 per Tcf, FVF= Formation Volume Factor (reservoir cf / thousand standard cf), GIIP=Gas Initially in Place, TRR=Technically Recoverable Resource,
Cumm Prdn = cumulative production through 2013, ERR= Economically Recoverable Resource, LS - limestone, SS = sandstone, dol = dolomite
* GIIP and TRR totals include four fields that are now inactive and not shown, field name (state, TCF GIIP): Estancia (NM, 0.9), Des Moines (NM, 1.0), Farnham (UT, 0.2) and Imperial (CA, 0.2)
Information Sources: (Adisoemerta, et al., 2004), (Ballentine, 2001), (Broadhead, 2009), (Lu, 2008), (Spangler, 2012), (Stilwell, 1989), (UGS, 2008), (Zimmerman, 1979).

1 Introduction

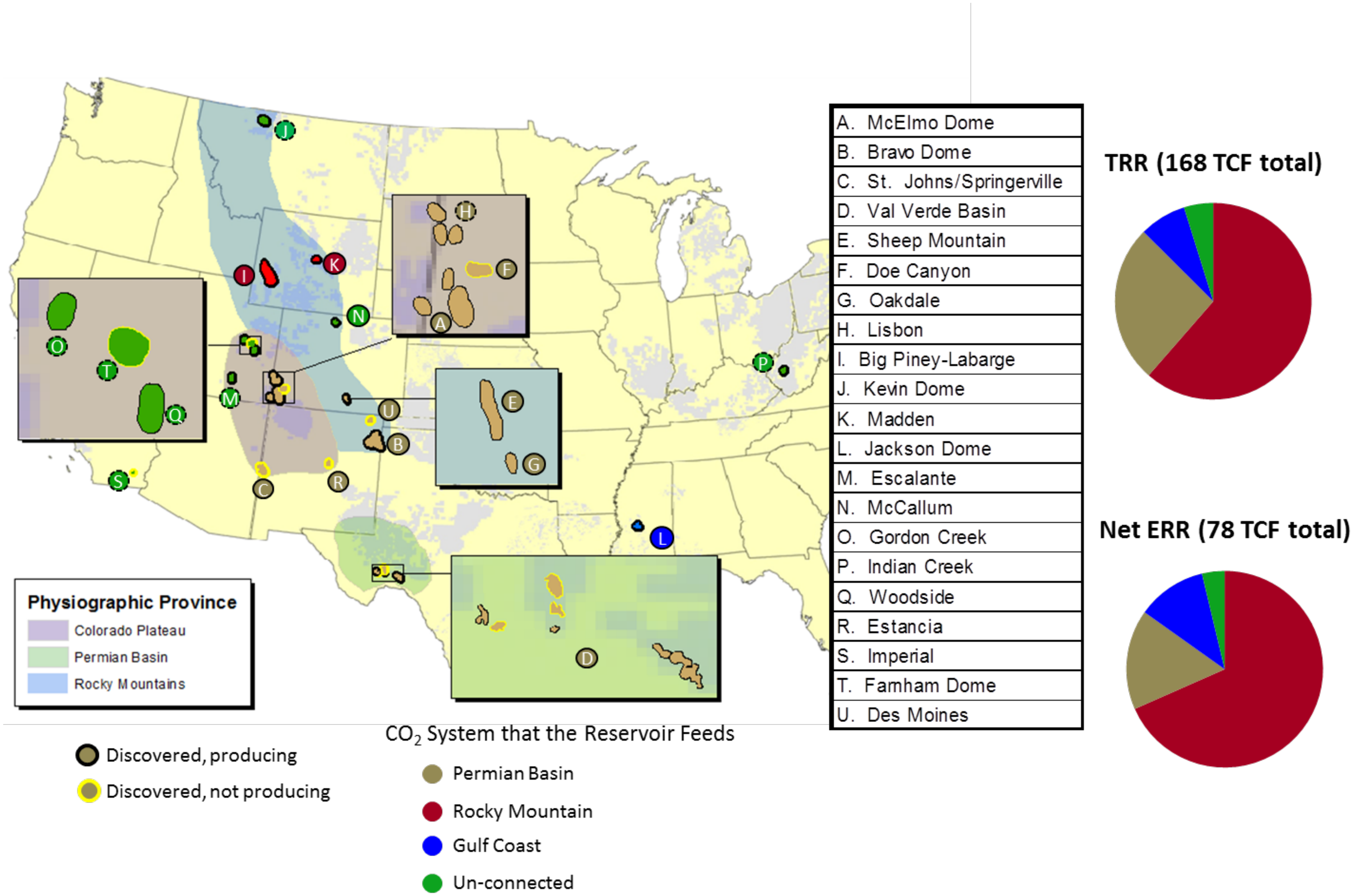
Uncertainty surrounding the need for carbon dioxide (CO_2) for enhanced oil recovery (EOR) from advanced fossil-fuel platforms exists due to the lack of a comprehensive United States (U.S.)-based resource estimate of CO_2 available from subsurface sources. At the same time, the exploration for subsurface CO_2 deposits is not well developed, as discovered CO_2 deposits have generally been the by-product of oil and gas exploration. The expansion of existing CO_2 reserves and estimates, and the identification of new major geologic plays of CO_2 could significantly impact the need for CO_2 from advanced fossil-fuel platforms beyond the 2030 timeframe. Given this set of circumstances, Energy Sector Planning and Analysis (ESPA) services for the National Energy Technology Laboratory (NETL) requested assistance from Enegis, LLC, to conduct a screening study to characterize the subsurface sources of CO_2 as an initial step to assess the impacts to national energy strategy.

This report serves to provide a quantitative estimate of the discovered geologic resources of CO_2 in the lower-48 U.S. Section 2 of the report presents an overview of discovered fields and discusses each, presenting a review of their geologic domain, parameters, and ancillary information. Section 3 presents the methodology for providing estimates of in-place, technically recoverable, and economically recoverable discovered subsurface sources of CO_2. Section 4 presents the results of the estimates and their discussion, including a comparison to recent, less comprehensive, estimates. The undiscovered resource base in the U.S. is being addressed in a companion volume to this report.

2 Discovered Sources of Geologic CO_2

Most CO_2 deposits discovered to date have been the by-product of exploration efforts for hydrocarbons. A survey of public-domain literature identified 21 fields or structures containing geologic CO_2 resources. An index map showing the status of the fields is shown in Exhibit 2-1. In the following section, each of the fields or structures is described by region in general order of size. The regions examined are the Rocky Mountains, Colorado Plateau, Permian Basin and other discoveries. A field location map is provided in Appendix 1 for each field; the maps are presented at the same scale to aid in the appreciation and understanding their relative size.

Exhibit 2-1 Subsurface sources of CO_2 in the U.S.



2.1 Rocky Mountains

The location of the CO_2 discoveries within the Rocky Mountains is shown in Exhibit 2-2. Exhibit 2-3 provides their geologic description and Exhibit 2-4 presents an estimation of original gas-initially-in-place (GIIP). Exhibit 2-5 shows their recovery and access factors.

Exhibit 2-2 Rocky Mountain CO_2 discoveries

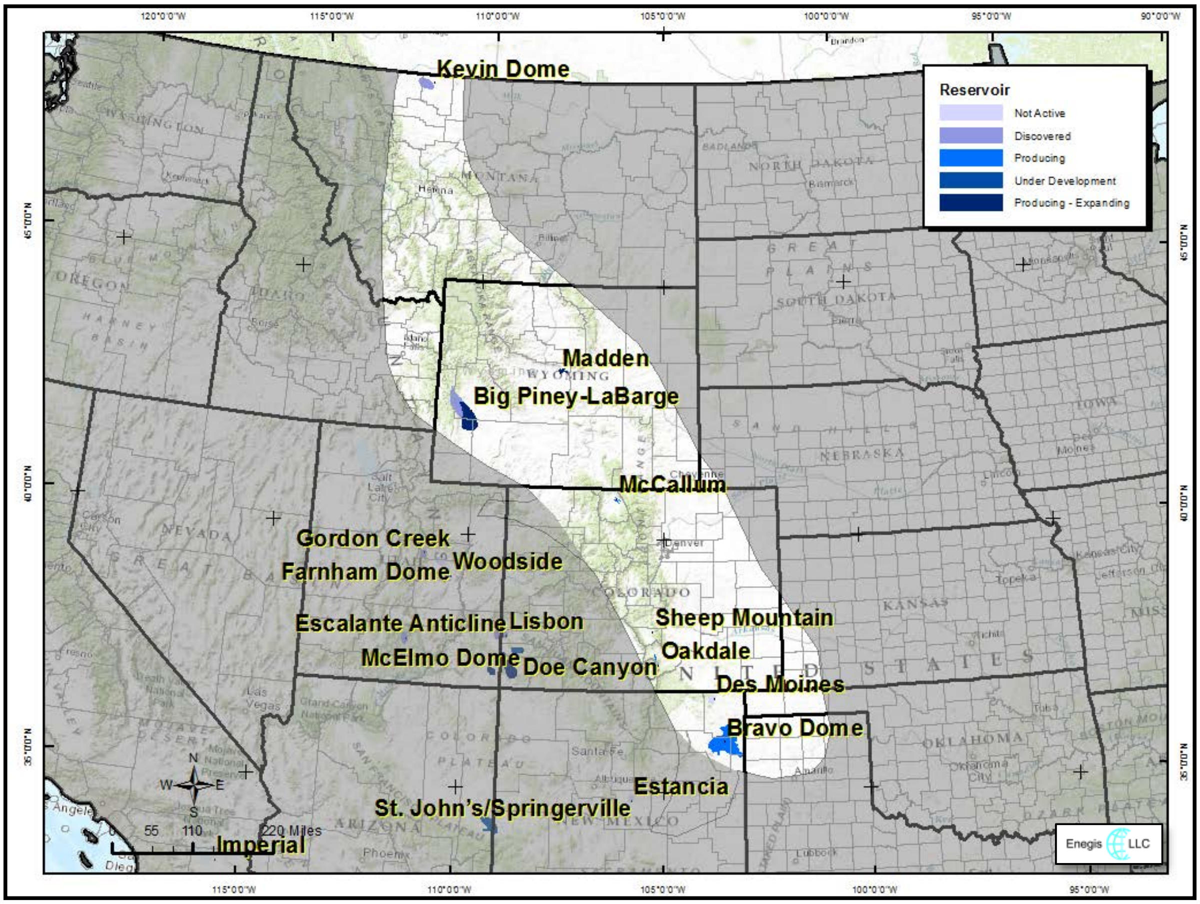


Exhibit 2-3 Geologic description and parameters of Rocky Mountain discoveries

CO_2 Assessment			Geologic Description	Depth	Net Pay	Fm Temp	Fm Pressure	Porosity
Structure or Field	State	Status		Feet	Feet	Deg F	Psi	%
Big Piney-LaBarge Basinal	WY	Producing*	Thrust, asymmetrical anticline; SS, dolomite, fractured basement; Sealed by Madison sabkha, karst breccia	15,680	275	225	6,585	9
Big Piney-LaBarge Foreland	WY	Producing	Thrust, asymmetrical anticline; SS, dolomite, fractured basement; Sealed by Madison sabkha, karst breccia	16,356	275	324	6,870	9
Big Piney-LaBarge Highland	WY	Discovered	Thrust, asymmetrical anticline; SS, dolomite, fractured basement; Sealed by Madison sabkha, karst breccia	18,154	275	349	7,625	9
Bravo Dome	NM	Producing	Anticlinal nose; Arkosic conglomerates SS, Tubb SS. Sealed by Cimarron Anhydrite, Chinle mudstone	2,550	125	80	641	20
Des Moines	NM	Inactive	Axial crest of Sierra Grande uplift; Lenticular arkosic conglomerates and SS. Sealed by interbedded red shales	2,330	50	78	137	20
Kevin Dome	MT	Discovered	Anticlinal culmination of Sweetgrass-North Battleford arch; Duperow Fm. Sealed by anhydrites	3,600	67	91	1,251	9
Madden	WY	Producing*	NW anticline; Madison dolomite. Sealed by Madison dolomite	23,700	175	335	11,021	15
McCallum	CO	Producing	Laramide anticlines; Dakota SS, Lakota SS, Nuddy SS. Sealed by Cretaceous Shales	5,500	100	120	2,316	20
Oakdale	CO	Discovered	Double-thrusted anticlines; Dakota SS, Entrada SS, Felsic dike	6,000	250	179	2,790	19
Sheep Mountain	CO	Producing	ENE anticline on Laramide Thrust; Dakota SS, Entrada SS. Sealed by Pierre Shale, laccolith	5,000	145	157	2,165	20

Notes: GIIP=Gas Initially in Place, TRR=Technically Recoverable Resources, Tcf=Trillion cubic feet, Bcf=Billion cubic feet. Conversion factor used=53 million tonnes CO_2 per Tcf.

*Expanding relative to CO_2 development

Exhibit 2-4 GIIP estimation for Rocky Mountain discoveries

CO_2 Assessment			Area	CO_2 Conc	Connate Water Sat.	Depth	Volume Factor	CO_2 GIIP	CO_2 Density
Structure or Field	**State**	**Status**	**Acres**	**%**	**%**	**Feet**	**Rscf/scf**	**10^6 Tonnes**	**mTonnes/ acre**
Big Piney-LaBarge Foreland	WY	Producing	137,830	74	15	16,356	0.003	29,627	214,957
Big Piney-LaBarge Basinal	WY	Producing*	387,876	85	15	15,680	0.003	113,009	291,354
Big Piney-LaBarge Highland	WY	Discovered	124,544	81	15	18,154	0.003	30,385	243,968
Bravo Dome	NM	Producing	700,000	97	50	2,550	0.016	23,107	33,010
Des Moines	NM	Inactive	58,157	99	20	2,330	0.020	1,003	17,250
Kevin Dome	MT	Discovered	440,000	88	20	3,600	0.005	13,824	31,418
Madden	WY	Producing*	79,500	20	20	23,700	0.004	3,828	48,145
McCallum	CO	Producing	15,250	92	20	5,500	0.004	2,797	183,400
Oakdale	CO	Discovered	3,400	72	20	6,000	0.004	1,153	339,096
Sheep Mountain	CO	Producing	12,200	97	20	5,000	0.004	3,066	251,352

Notes: GIIP=Gas Initially in Place, TRR=Technically Recoverable Resources, Tcf=Trillion cubic feet, Bcf=Billion cubic feet.
Conversion factor used=53 million tonnes CO_2 per Tcf.

*Expanding relative to CO_2 development

Exhibit 2-5 Recovery and access for Rocky Mountain discoveries

CO_2 Assessment			CO_2 GIIP	Recovery Factor	Access Factor	CO_2 TRR	Comments
Structure or Field	State	Status	10^6 Tonnes	%	%	10^6 Tonnes	
Big Piney-LaBarge Foreland	WY	Producing	29,627	70	80	16,591	Access limited by Bridger-Teton National Forest\BLM wildlife concerns, e.g., big game, and sage grouse
Big Piney-LaBarge Basinal	WY	Producing*	113,009	70	85	67,241	Access limited by big game, sage grouse and other BLM wildlife stipulations
Big Piney-LaBarge Highland	WY	Discovered	30,385	70	30	6,381	Access limited by Bridger-Teton National Forest steep slopes and no leasing areas
Bravo Dome	NM	Producing	23,107	65	90	13,518	Lower recovery due to poor quality reservoir from interbedded impermeable muddy sediments
Des Moines	NM	Inactive	1,003	65	90	587	Lower recovery due to poor quality reservoir from interbedded impermeable muddy sediments
Kevin Dome	MT	Discovered	13,824	75	95	9,850	Recovery factor based on Spangler (Spangler, 2012)
Madden	WY	Producing*	3,828	70	95	2,545	N/A
McCallum	CO	Producing	2,797	70	90	1,762	N/A
Oakdale	CO	Discovered	1,153	65	80	600	Lower recovery due to volcanic reservoir. Access limited by San Isabel National Forest/Wilderness
Sheep Mountain	CO	Producing	3,066	65	80	1,595	Lower recovery due to tight reservoir. Access limited by San Isabel National Forest/Wilderness

*Expanding relative to CO_2 development

2.1.1 Big Piney-LaBarge, WY

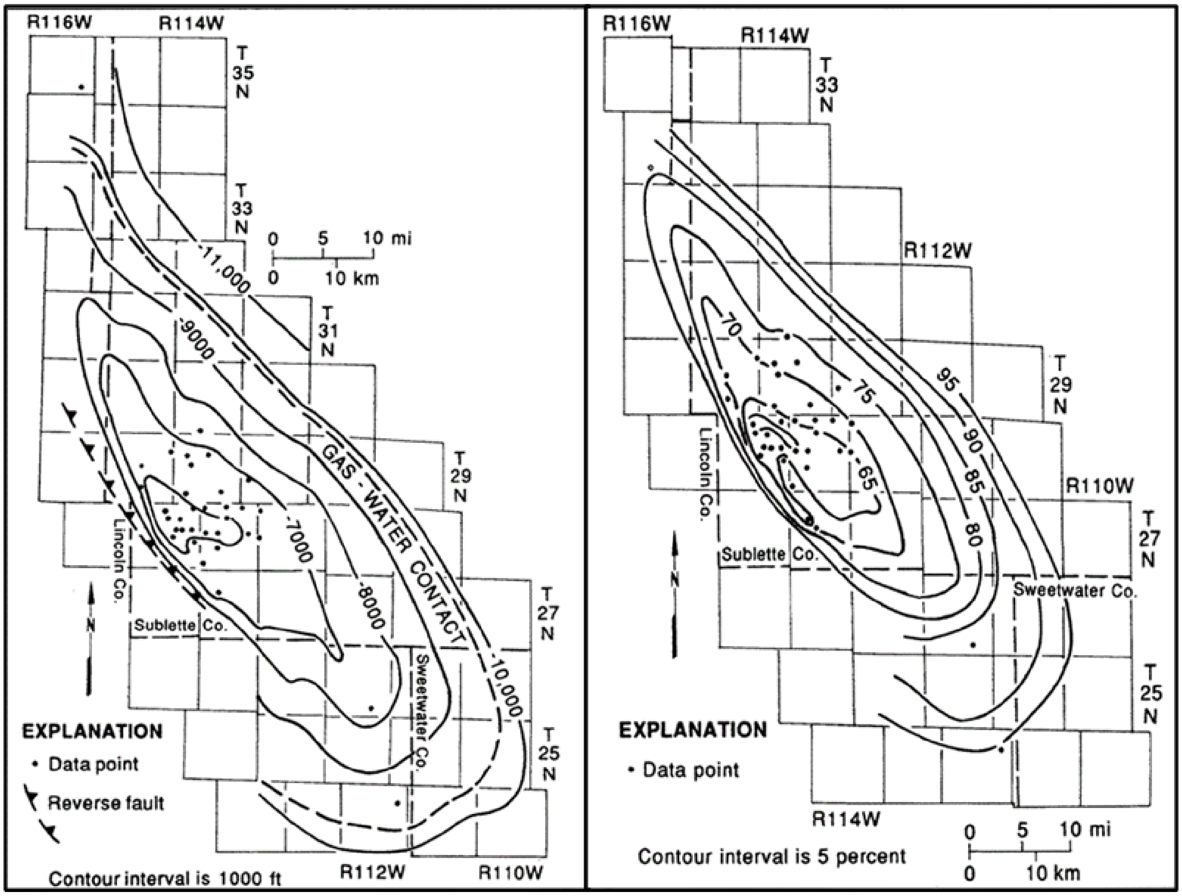
The Big Piney-LaBarge field (BPLB) is large, comprising 650,000 acres in south Sublette County and northeast Lincoln County, 25 miles north of Kemmerer, Wyoming, in the west-central part of the Green River basin. The field is located on a large structural high, known as the LaBarge platform. For purposes of this analysis, BPLB was divided into three subfields—basinal, foreland, and highland areas—as a function of accessibility and drill depth.

In BPLB, the reservoir is the Mississippian Madison Formation, which comprises a thick carbonate reservoir, ranging from 14,000 feet below surface in the southwest and plunging to 19,000 feet in the northeast. The lower Madison Formation is made up of shallow-shelf dolomitized limestone and dolomite. The reservoirs are overlain and sealed by the Upper Madison sabkha deposits. The trap is a large anticline with a relatively steeper dips on its west flank, where it is bounded by an east-dipping thrust fault. (Denbury, July 2013) Porosity ranges from 6 to 12 percent (Stilwell, 1989); permeability is 10 to 50 mD. (Denbury, July 2013) Prior to Tertiary deposition, the LaBarge platform was a large doubly-plunging anticline. Subsidence of the Green River basin to the northeast followed by Tertiary deposition has resulted in generally east-northeast dips. The western flank of the LaBarge platform has been modified by thrust faulting. A number of anticlinal folds with associated high-angle reverse faults and tear faults have been encountered on the platform. On some of these folds, such as the one defining the LaBarge field, the initial movement was prior to Tertiary deposition, and the associated reverse faulting is upthrown to the east.

Stilwell presents a top Madison structure map along with a corresponding CO_2 concentration map, shown in Exhibit 2-6. (Stilwell, 1989) These maps were integrated in a Geographical Information System (GIS) along with the topographic information. The resultant polygons were attributed and modeled with discrete combinations of drill depth and CO_2 concentration. The accessibility of resources for actual drilling was also incorporated into the GIS as discussed in Section 3, which shows an example for BPLB. Exhibit 2-7 shows the GIS-based analysis performed, resulting in the attributes of the highlighted polygon.

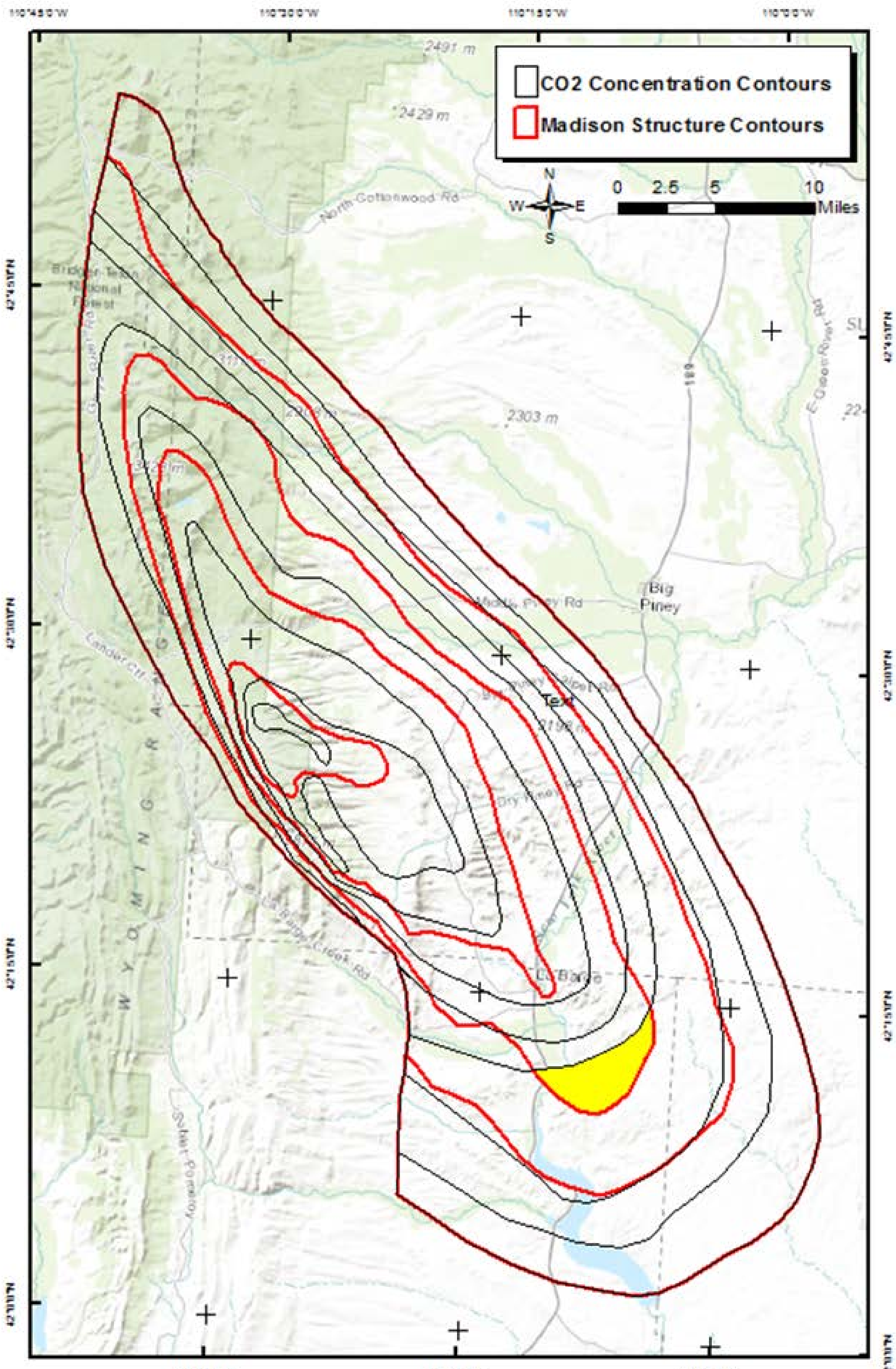
Drilling activity in the Big Piney gas field began in 1952, and was successful with the market provided by the Pacific Northwest natural gas pipeline, running from the San Juan basin in southern Colorado to the state of Washington. (Stilwell, 1989) Today, the Big Piney-LaBarge complex, consisting of the Tiptop, Dry Piney, Hogsback, LaBarge, and Big Piney oil and gas fields, produces to the Shute Creek gas plant with a natural gas capacity of 600 million cubic feet per day (MMcfd). ExxonMobil's average well produces 45 MMcfd, (Khayyal, July 2013) with which modeling presented in this report is consistent. Sales capacity at Shute Creek is 340 MMcfd. The gas processed is typically two-thirds CO_2. Approximately 100 MMcfd CO_2 is piped to Rangely oil field in Colorado, (NETL, undated) and 75 MMcfd is piped to Lost Soldier and Wertz oil fields in Wyoming, for tertiary oil recovery. In the past, about 225 MMcfd of CO_2 were vented to the atmosphere due to a lack of markets, (NETL, undated) a situation that is changing with the increased demand for CO_2 in EOR. The field currently produces about 215 MMcfd of CO_2, and ExxonMobil is installing increased compression capability (Condon, 2011) to address the EOR markets. CO_2 production is also established at the Riley Ridge facility, operated by Denbury Resources. (Denbury, 2012) In addition to CO_2, produced gases include helium and H_2S. The H_2S is re-injected. It is assumed that in modeling this field, costs associated with H_2S reinjection are three-quarters that of sulfur extraction.

Exhibit 2-6 Top Madison structure and CO_2 content



Used with permission (Stilwell, 1989)

Exhibit 2-7 GIS Methodology at Big Piney-LaBarge



Modified and used with permission (Stilwell, 1989)

2.1.2 Bravo Dome, NM

Bravo Dome (originally the Bueyeros field) is a large field, comprising 700,000 acres located in Union, Harding, and Quay Counties, 30 miles to the southwest of Clayton, New Mexico. Bravo Dome is a northwest-trending anticlinal nose situated on the spur of the Sierra Grande arch. The region is bounded by the Tucumari basin to the south and the Dalhart basin to the north.

Bravo Dome field is a combination structural stratigraphic trap caused by the thinning and loss of permeability in the Permian Tubb Sandstone to north and west across a southeast plunging arch on the east edge of the Sierra Grande uplift. The reservoir is scaled below by granite in the west and by impermeable shales and tight sandstones in the east. It is sealed above by impermeable anhydrite of the Cimmaron Anhydrite and shales of the Upper Clearfork Formation (Cassidy, 2005). Bravo Dome produces from the Permian Tubb Formation at relatively shallow depths of around 2,550 feet. (Broadhead, 2009) The Tubb Formation is an arkosic sandstone formed by sand-dominated alluvial, fluvial, and eolian deposition with an average thickness of 125 feet. (Cassidy, 2005) (Zimmerman, 1979) (NETL, undated) Tubb deposition apparently did not occur to the northwest of the structure, resulting in a depositional pinch-out on the Sierra Grande Uplift. Tubb thickness increases rapidly down-dip, to a maximum of 500 feet in the southeastern portion of the structure. The Tubb pinch-out limits productivity in the northwestern portion of the structure. An apparent gas water contact limits productivity down-dip in the southeastern and southwestern portions of the structure.

CO_2 is trapped by a combination of stratigraphic pinch-out and fold closures. The reservoir is sealed by the impervious Cimarron anhydrite, which is a mixture of shallow marine evaporates and arkosic muds. Average porosity and permeability are 20 percent and 42 millidarcy (mD) respectively. (NETL, undated)

Bravo Dome was accidentally discovered in 1916, during petroleum exploration; development commenced in 1931. It was expanded throughout the 1930s to 19 wells, which produced modestly until the end of the 1970s. An additional 270 wells were drilled in the 1980s, in order to satisfy the demand for CO_2 for EOR in west Texas. (Broadhead, 2009) Production is approximately 120 billion cubic feet (Bcf) per year from 250 wells. (Broadhead, 2009)

2.1.3 Des Moines, NM

The Des Moines field is located in northwestern Union County, 35 miles east of Raton, New Mexico, and 35 miles northwest of Bravo Dome. The field is located near the axial crest of the Sierra Grande uplift. The primary reservoirs are lenticular arkosic conglomerates and conglomeratic sandstones of the Permian Abo Formation. The formation rests unconformably on Precambrian basement in the area. Interbedded red shales act as seals. Depth to production averages 2,300 feet, with 50 to feet of net pay. (Broadhead, 2009)

The field was discovered in 1935. Four additional productive wells were drilled during the 1950s, and a processing plant was built to convert the CO_2 into liquid CO_2 and dry ice. (Broadhead, 2009) The field produced until 1966, when it was abandoned because of problems related to gas processing. Cumulative production from the Des Moines field is estimated to have produced about 20 Bcf.

2.1.4 Kevin Dome, MT

Kevin Dome is located on the western flank of the Williston basin along the U.S.-Canadian border in southwestern Saskatchewan and northern Montana, 30 miles northwest of Havre, Montana. The majority of the field is located in Canada with its southern extent located in the U.S. In the area of Kevin Dome, the structure of western North America has been influenced by crustal shortening associated with the Antler orogeny in Upper Devonian time. Further crustal shortening and uplift occurred in the region during the Laramide orogeny in early Tertiary Time. In Montana, major structural elements include the north-trending Sweetgrass–North Battleford arch, (Lake, 2006) upon which Kevin Dome is a large anticlinal culmination along its axis. The deposit covers over 280,000 acres with approximately 750 feet of structural relief. The area of Kevin Dome was calculated based on Spangler (Spangler, 2012) and a Montana Geological Society (MGS, 1985) structural map on the Madison Formation, assuming persistent compartmentalization at the Duperow level, and a tightening of the fold with depth. As discussed in Section 3.2.2, wells drilled in the Upper Duperow are dual-completed in the Lower Duperow formation.

At Kevin Dome, the Duperow Formation shows facies variability both laterally and vertically that results in thin, widespread depositional cycles that are suggestive of a stable cratonic and climatic environment. Duperow strata generally exhibit shallowing-upward cycles of carbonate deposition in very shallow settings that often are capped by evaporite deposits. These anhydrite-dominated layers at the top of individual cycles often serve as effective seals to fluid migration. (Lake, 2006)

Geologically occurring CO_2 has been documented in several oil and gas wells drilled over the past 50 years, which have penetrated the Upper Devonian Duperow Formation, although reservoir characteristics are not well understood. The Duperow averages 75 feet of net thickness with 9 percent porosity. Gases average 88 percent CO_2 with the balance of gas being nitrogen. (Spangler, 2012)

2.1.5 Madden, WY

The Madden gas field is in the Wind River basin, in Fremont County, fifteen miles north-northeast of Shoshoni, Wyoming. The double-plunging Madden anticline was a deep basin play beneath the southwest vergent Wind River thrust. Produced natural gases from the Madden field contain 67 percent methane and about 20 percent CO_2. Conoco Phillips previously vented 50 MMcfd from its Lost Cabin Gas Processing facility, (ConocoPhillips, undated) which is now being converted to capture CO_2 for use in EOR. According to Conoco-Phillips, sulfur derived from production at the field is marketed. (ConocoPhillips, undated)

2.1.6 McCallum, CO

McCallum anticline is a modest-sized field located in McCallum County, 50 miles northwest of Estes Park, Colorado, in the North Park basin. The field comprises two large anticlines, North McCallum anticline, and the faulted en-echelon South McCallum anticline that is structurally juxtaposed on the southeast. CO_2 is trapped in late Laramide-related anticlines and faulted anticlines in a combination of structural and stratigraphic traps. (Stevens, May 15-17, 2001)

The field produces from the Lower Cretaceous Dakota and Lakota formations. The reservoirs average 5,500 feet in depth and about 100 feet net thickness. (Gilfillan, 2008) The Dakota

Sandstone consists of intertongued beds of fluvial shoreline sandstone, carbonaceous siltstone, claystone, and conglomeratic sandstone. Individual reservoir thicknesses average 25-40 feet, with an average porosity of 18 to 20 percent. (Wandrey, undated) The Lakota Sandstone consists of medium-to-coarse-grained sandstone and conglomerate. Reservoir thicknesses average about 100 feet. (Wandrey, undated)

The field was first discovered in 1925, and has produced approximately 870 Bcf of CO_2 since 1927. As of 2001, four wells were in operation with the field producing around 38 Bcf per year of CO_2 for industrial use. (Stevens, May 15-17, 2001)

2.1.7 Oakdale, CO

Oakdale is a small (3,400 acres) field located in the northern Raton basin, in Huerfano County, 20 miles west-southwest of Walsenburg, Colorado, and five miles southeast of the larger Sheep Mountain field. The field is a subthrust play and consists of a double-thrusted anticline located in the footwall of the Sangre de Cristo (main) thrust and in the hanging-wall of the Oakdale thrust. The Raton basin sedimentary succession was folded and thrust faulted during the Laramide orogeny (Late Cretaceous through Eocene time) when the Sangre de Cristo Mountains were formed. The thrusting and folding that formed the north-northwest to south-southeast trending, double-plunging Oakdale anticline is the product of at least two episodes of thrust faulting. (Worrall, 2003)

Pay zones include the Dakota and Entrada sandstones and one unconventional zone, which is a three-hundred-feet thick, shallow-dipping, felsite dike that has both primary and secondary fracture porosity and permeability. The Dakota Sandstone is typically about 200 feet thick within and around the north Raton basin. It consists of two beds of white-to-buff, well-sorted, cross-stratified, fine-to-medium grained, quartzitic sandstone, and a very thin interbed of black carbonaceous shale. (USGS, 1959) The much thinner and less continuous Entrada Sandstone is slightly less than 100 feet thick. The Entrada sandstone lies disconformably on the uppermost red beds of the Sangre de Cristo Formation. The formation consists of light-gray-to-buff, thick-to-massive, well-rounded, fine-to-medium grained quartzitic sandstone. The formation tends to increase in thickness toward the north and northeast of Oakdale (Johnson, 1959). Both the Dakota and Entrada Sandstone reservoirs have twice as much porosity as typically seen elsewhere in the Raton basin.

Each of the three reservoirs at Oakdale contains gases of radically different composition, varying from 24 percent to 97 percent CO_2, and 3 percent to 75 percent oil or methane. The small (370 acres) microgranite Maestas stock and associated dikes are the likely "source rocks" for the adjoining, primitive, ^{3}He-bearing CO_2 gas found at Oakdale and Sheep Mountain. Worrall estimated total reserves for the Dakota and Entrada sandstones at 450 Bcf in place with a gas column of 1,000 feet. (Worrall, 2003) All three reservoirs (the Dakota and Entrada formations and the felsites dike) were evaluated in this assessment based on estimated average properties for the three units.

2.1.8 Sheep Mountain, CO

The Sheep Mountain gas field is located at the northern end of the Raton basin, in Huerfano County, 20 miles west of Walsenberg, Colorado, and five miles northwest of the Oakdale field. The Sheep Mountain and Oakdale anticlines are subthrust anticlines beneath the Sangre de Cristo thrust. These upright, open, double-plunging foreland folds are aligned along a common northwest-trending axial trace and are Laramide-aged (60-45 millions of years ago (Ma)) imbricate thrusted folds, which share common styles and modes of deformation.

The Raton basin sedimentary succession was folded and thrust-faulted during the Laramide orogeny when the Sangre de Cristo Mountains were formed. Folding and overthrusting created the Malachite syncline and the little Sheep Mountain anticline. This northwest-trending anticlinal fold is bounded on the northeast side by a minor thrust fault and forms the structural trap of the field.

Methane and CO_2 gases and oil are reservoired within the 70-feet-thick Entrada and 200-feet-thick Dakota sandstones as well as an overlying, shallow west southwest-dipping, 300 feet thick, Oligocene felsite dike emplaced along and within the low-angle west southwest-dipping La Veta thrust. Combined, the three formations comprise 145 feet of net pay. The dike is highly fractured and shows good fracture permeability and porosity as well as primary intra-matrix porosity. This unusual reservoir is viewed as a significant component of the CO_2 resource at the nearby Oakdale field. (USGS, 2007) The reservoir produces at an average depth of 5,000 feet (Broadhead, 2009). Gases are 97 percent CO_2 with 2 percent N_2.

Production began in 1983, and has continued at an average rate of 70 Bcf/year, with cumulative production to 1999 estimated at 1.2 Tcf. (NETL, undated) The gas is refined and pumped via pipeline to west Texas, where it is used for EOR.

2.2 Colorado Plateau

The location of the CO_2 discoveries within the Colorado Plateau is shown in Exhibit 2-8. Exhibit 2-9 provides their geologic description and Exhibit 2-10 presents an estimation of original GIIP. Exhibit 2-11 shows their recovery and access factors.

Exhibit 2-8 Colorado Plateau CO_2 discoveries

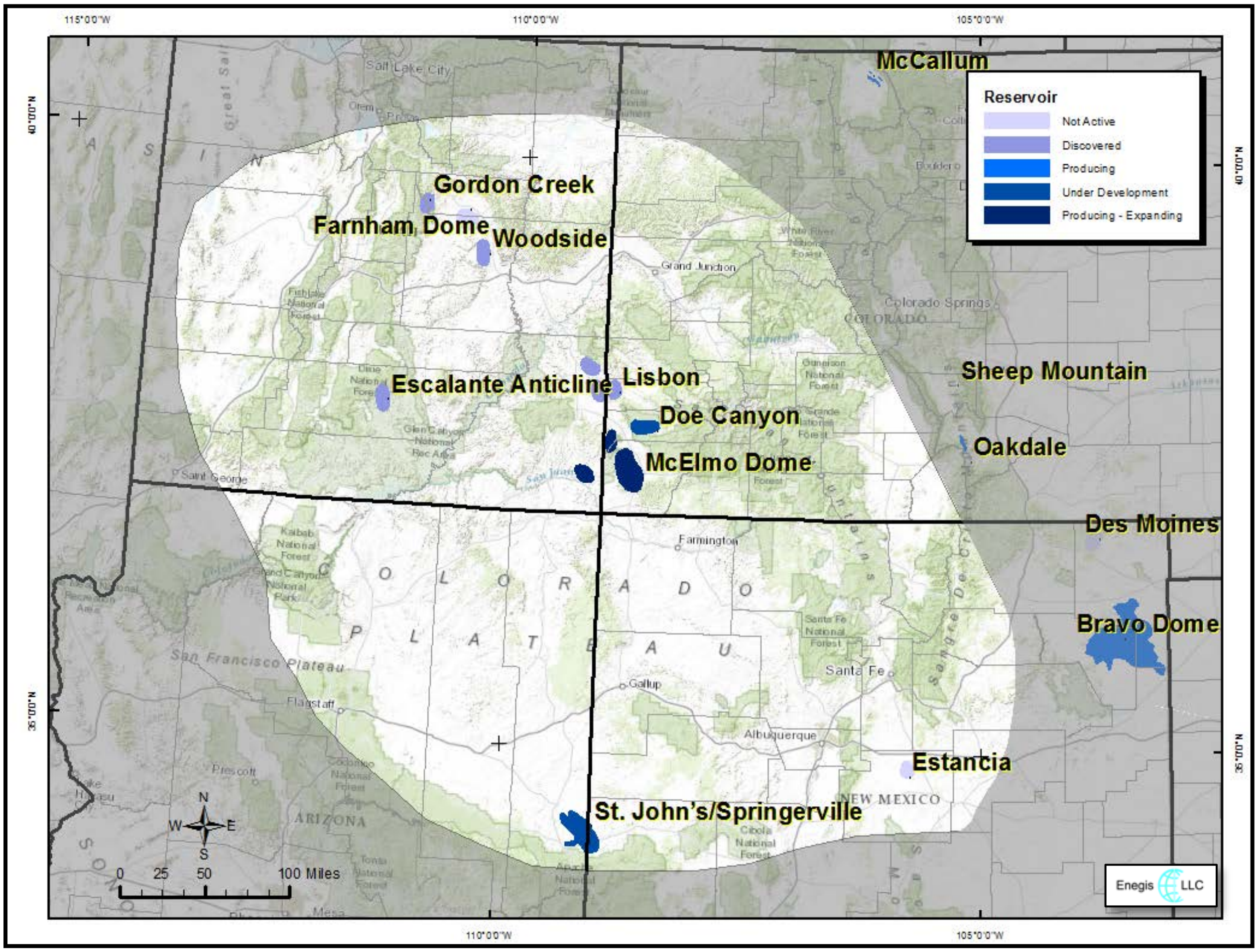


Exhibit 2-9 Geologic description and parameters of Colorado Plateau discoveries

CO_2 Assessment			Geologic Description	Depth	Net Pay	Fm Temp	Fm Pressure	Porosity
Structure or Field	State	Status		Feet	Feet	Deg F	Psi	%
Doe Canyon	CO	Under development	Anticlines; Leadville LS. Sealed by Paradox salt-anhydrite	9,000	60	213	3,960	10
Escalante Anticline	UT	Discovered	N-NW Laramide anticline; Cedar Mesa SS, Kaibab LS karst. Sealed by Organ Rock Fm shale	2,272	172	95	1,057	7
Estancia	NM	Inactive	Asymmetric Laramide Anticline; Cedar Mesa SS, White Rim SS, Toroweap Fm, Kaibab LS, Chinle Fm.	1,475	65	81	400	14
Farnham Anticline	UT	Discovered	N-S trending anticline; Navajo SS. Sealed by Carmel shale	4,000	40	110	2,200	12
Gordon Creek	UT	Discovered	NE-SW trending anticline; White Rim Fm, Sinbad LS.	12,579	135	214	6,566	9
Lisbon	UT	Discovered	Leadville LS reservoirs	9,600	75	224	3,200	12
McElmo Dome	CO, UT	Producing	NW Plunging anticlines; Leadville LS. Sealed by Paradox salt-anhydrite	8,000	95	196	3,520	12
St. Johns/ Springerville	NM, AZ	Under development	Asymmetrical anticline; Supai Fm arkosic SS. Fractured basement. Sealed by San Andreas Anhydrite, Moenkopi LS	1,526	75	88	508	15
Woodside	UT	Discovered	Double-plunging anticline; White Rim SS	3,500	45	103	1,628	9

Notes: GIIP=Gas Initially in Place, TRR=Technically Recoverable Resources, Tcf=Trillion cubic feet, Bcf=Billion cubic feet.
Conversion factor used=53 million tonnes CO_2 per Tcf.

Exhibit 2-10 GIIP estimation for Colorado Plateau discoveries

CO_2 Assessment			Area	CO_2 Conc	Connate Water Sat.	Depth	Volume Factor	CO_2 GIIP	CO_2 Density
Structure or Field	**State**	**Status**	**Acres**	**%**	**%**	**Feet**	**Rscf/scf**	**10^6 Tonnes**	**Tonnes/ acre**
McElmo Dome	CO, UT	Producing	201,500	98	20	8,000	0.003	30,095	149,357
Doe Canyon	CO	Under development	82,078	95	20	9,000	0.003	5,095	62,073
Escalante Anticline	UT	Discovered	185,000	95	20	2,272	0.010	10,082	54,495
Estancia	NM	Inactive	47,750	98	20	1,475	0.015	989	20,718
Farnham Anticline	UT	Discovered	3,600	99	35	4,000	0.002	202	56,062
Gordon Creek	UT	Discovered	16,800	99	20	12,579	0.002	1,720	102,408
Lisbon	UT	Discovered	3,200	90	20	9,600	0.004	238	74,281
St. Johns/ Springerville	NM, AZ	Under development	220,125	93	20	1,526	0.009	8,917	40,511
Woodside	UT	Discovered	12,800	32	20	3,500	0.005	111	8,685

Notes: GIIP=Gas Initially in Place, TRR=Technically Recoverable Resources, Tcf=Trillion cubic feet, Bcf=Billion cubic feet.
Conversion factor used=53 million tonnes CO_2 per Tcf.

Exhibit 2-11 Recovery and access for Colorado Plateau discoveries

CO_2 Assessment			CO_2 GIIP	Recovery Factor	Access Factor	CO_2 TRR	Comments
Structure or Field	State	Status	10^6 Tonnes	%	%	10^6 Tonnes	
Doe Canyon	CO	Under development	5,095	70	75	2,675	Access limited by San Juan National Forest
Escalante Anticline	UT	Discovered	10,082	55	45	2,495	Lower recovery due to variable quality and tight reservoir, poor porosity. Access limited by Box-Death Hollow Wilderness/Phipps Death Hollow Wilderness Study Area
Estancia	NM	Inactive	989	60	95	564	Lower recovery due to anticipated lower permeability reservoir
Farnham Anticline	UT	Discovered	202	70	45	64	Access limited by Turtle Canyon Wilderness Study Area
Gordon Creek	UT	Discovered	1,720	65	90	1,006	Lower recovery due to variable quality and tight reservoir, poor porosity. Access limited by Manti la Sal National Forest
Lisbon	UT	Discovered	238	70	85	141	Access limited by Dolores River Canyon Wilderness Study Area, Manti la Sal National Forest
McElmo Dome	CO, UT	Producing	30,095	70	65	13,693	Access limited by Native American archeological concerns, Canyon of the Ancients National Monument, Several Wilderness Study Areas
St. Johns/ Springerville	NM, AZ	Under development	8,917	70	80	4,994	N/A
Woodside	UT	Discovered	111	60	90	60	Lower recovery due to variable quality and tight reservoir, poor porosity. Access limited by Desolation Canyon Wilderness Study Area

2.2.1 Doe Canyon, CO

The Doe Canyon field is in central Dolores County, north of Cortez, Colorado, and the McElmo Dome CO_2 field. The field produces from the Mississippian Leadville and Ouray formations. Geologically, the field is similar to nearby McElmo Dome.

Kinder Morgan CO_2 purchased the Doe Canyon field from Shell CO_2 in 2006. In February 2012 Kinder Morgan CO_2 announced expansion of the field, drilling 19 additional wells and increasing production into the Cortez pipeline from 105 MMcfd to 170 MMcfd. (Wiseman, 2012) It should be noted that Doe Canyon is largely located within the San Juan National Forest, where while not necessarily prohibiting exploration and development, compliance with wildlife, environmental, and other land-use stipulations in the forest likely will present significant logistical issues.

2.2.2 Escalante Anticline, UT

The Escalante anticline is located in central Garfield County in southern Utah, 20 miles southwest of Capital Reef National Park. The structure is located in the northern Kaiparowits basin and covers 37,000 acres. The anticline is asymmetric with steepest dips vergent toward the west. It is one of many secondary folds of this Laramide-age structural basin. (NETL, undated)

The Permian and Triassic CO_2 reservoirs at Escalante field comprise numerous rock types deposited in a variety of environments. The Permian Cedar Mesa and White Rim sandstones represent near-shore-beach-to-dune deposits and are composed of porous, cross-bedded, fine-to-medium grained sandstone. The Cedar Mesa Sandstone averages 3,150 feet deep with a net thickness of 250 feet. In between the Cedar Mesa and White Rim is the shallow-marine Toroweap Formation. The Toroweap consists of very fine-grained dolomite interbedded with thin, fine-grained sandstone and shale. The Toroweap and White Rim formations average 2,580 feet in depth and 195 feet combined net thickness. The Permian Kaibab limestone was also deposited in a widespread shallow sea. The Kaibab consists of very-fine to fine-grained limestone and dolomite with thin interbedded sandstone and shale. The Kaibab averages 2,300 feet deep and 125 net thickness. The Triassic Timpoweap Member of the Moenkopi Formation is a fine-grained, dense carbonate deposited in a near-shore marine environment. The Timpoweap averages 2,200 feet deep and about 82 feet net thickness. The Shinarump Member of the Triassic Chinle Formation was deposited by northwest-flowing steams in a river flood plain. The Shinarump Member consists of porous, medium-to-coarse grained sandstone. The Shinarump Member averages 1,300 feet deep with 225 feet net thickness.

Gas composition averages about 95 percent CO_2 with 2-to-5 percent N_2. Porosity ranges from 12-to-16 percent within the sandstone reservoirs to 6-to-8 percent in the carbonates. The potential source of the CO_2 in the Escalante anticline is likely magmatic and associated with the High Plateau volcanic province.

The Escalante field was discovered in 1960, by Phillips Petroleum. There has been no production of CO_2 from Escalante field.

2.2.3 Estancia Basin, NM

The Estancia CO_2 fields are located in Torrance County, 25 miles southeast of Edgewood, New Mexico. The two fields are known informally as the northern and the southern Estancia fields and are drilled near the crest of the Wilcox anticline. The structure has been mapped at the surface as a doubly-plunging anticline with 60 to 80 feet of structural closure. The trap appears to be structural, but the down-dip boundaries of the field have never been defined by drilling. It is not known if there is a stratigraphic component to trapping. (NETL, undated) Based on this, the fields were analyzed in this assessment as a single unit.

The northern field was discovered in 1931. Seven productive wells were drilled between 1934 and 1937. (NETL, undated) The reservoirs for the northern Estancia field are associated with sandstones of the Sandia Formation. The produced gas was converted into dry ice at a nearby processing plant.

The southern Estancia field was discovered in 1928. CO_2 was encountered between depths of 1,645 feet and 1,760 feet. Although data are vague, it appears that the gas was reservoired by a sandstone bed within the Sandia Formation. In all, three wells produced CO_2 from the southern

Estancia field. The trapping mechanism at the southern Estancia field has not been defined. (NETL, undated)

CO_2 was first produced from the Estancia fields in 1934. In that year, a plant was built to convert the CO_2 gas into dry ice. The plant produced dry ice until 1942. Cumulative production from the Estancia fields is estimated to be 14 Bcf. (Broadhead, 2009)

2.2.4 Farnham Anticline, UT

The small (3,600 acres) Farnham anticline is located in Carbon and Emery Counties, three miles southeast of Price, Utah, in the Uintah basin. It lies 20 miles east of the Gordon Creek field and 20 miles northwest of the Woodside CO_2 field. The anticline is asymmetric, west-vergent with a tight, steep forelimb and broad gently-east-dipping backlimb. Reservoirs include the Upper and Lower Jurassic Navajo Sandstone and the Sinbad Limestone Member of the Moenkopi Formation. The average porosity is 12 percent intergranular, in a moderately homogenous eolian sandstone. The trap is both structural and stratigraphic, sealed by interbedded limestone and shale of the Jurassic Carmel Formation. The reservoir averages an estimated 40 feet of net pay, and gas composition is 98.9 percent CO_2 with minor N_2. (NETL, undated) (Chidsey, 2007)

Production first began in 1931. The field produced 4.8 Bcf, which was pipelined to a nearby dry-ice plant. In 1972, the field was shut in when the dry-ice plant was closed.

2.2.5 Gordon Creek, UT

The Gordon Creek field is located in Carbon and Emery counties in the Uintah basin, 10 miles west of Price, Utah, and 20 miles west of the Farnham Dome CO_2 field. Gordon Creek was discovered in 1947 has produced 8,500 Mcfd from both the Permian White Rim Sandstone and Sinbad Limestone Member of the Triassic Moenkopi Formation. The trap is a northeast-southwest-trending anticline. The high flow rates from these units suggest the presence of an extensive fracture system.

The White Rim Formation is an eolian dune deposit with an average drill depth of 12,800 feet and 9 percent porosity. (NETL, undated) The Sinbad is a fine-grained, dense carbonate deposited in a near-shore marine environment. It averages 11,000 feet deep and 6 percent porosity. (NETL, undated) CO_2 concentrations in both formations are above 98 percent. There has been no production of CO_2 from the Gordon Creek field.

2.2.6 Lisbon, UT

The Lisbon CO_2 fields comprise three small (3,200 total acres) units in San Juan County, Utah and San Miguel County Colorado, 20 miles northeast of Monticello, Colorado. They lie 35 miles northwest of the Doe Canyon field. CO_2 is found in the Mississippian Leadville Limestone at an average depth of 9,600 feet. (UGS, 2008)

2.2.7 McElmo Dome, CO, UT

McElmo Dome comprises a large anticline with satellite structures, comprising 201,500 acres. It is situated at the southeastern end of the Paradox basin in the Four Corners area, five miles west of Cortez, Colorado, in the center of the Colorado Plateau. The surrounding surface geology is dominated by flat-lying sedimentary stratigraphy. It is surrounded by smaller satellite fields to the northwest and west, and the Doe Canyon field to the northeast.

Supercritical CO_2 is stored within two productive zones, the Mississippian Leadville and the Devonian Ouray formations, found at depths of 6,500-9,000 feet subsurface. Both formations are composed of limestones and dolomites, with the Leadville providing greater productivity.

Produced gas from both formations comprises 96 to 99 percent CO_2 with 1 to 4 percent N_2. (NETL, undated) The reservoir structure is complex, consisting of interbedded porous permeable dolomite and tight limestones and less than 100 feet in net thickness (NETL, undated) and averages 8000 feet in depth. (Kinder Morgan CO2, 2013) The trap is a combination of structural closure, permeability barriers within the Leadville, and a 1,200 ft thick salt-cap rock of the Paradox Formation. Porosity averages 12 percent. (NETL, undated)

McElmo Dome was discovered in 1948, and is currently operated by Kinder Morgan CO_2. Average annual production since 1995 has ranged from 220–310 Bcf. (NETL, undated) Total cumulative production to date is 7.2 Tcf. (DiPietro, 2012) Commercial production commenced in 1984 with completion of a 500-mile Cortez CO_2 pipeline, which supplies CO_2 for EOR projects in the Permian basin. A total of 59 CO_2 production wells have been drilled at McElmo Dome since 1976. Most wells can deliver 20 MMcfd. The two-phase CO_2 present is dehydrated, compressed, and delivered to the Cortez pipeline. (Stevens, May 15-17, 2001) Kinder Morgan CO_2 is currently expanding production at the field by 1.2 billion cubic feet per day (Bcfd). (Bradley, 2013)

2.2.8 St. Johns/Springerville, NM, AZ

St. Johns Dome is a large (220,000 acre) asymmetrical faulted anticline situated on the southern margin of the Colorado Plateau on the Arizona/New Mexico border, 10 miles northeast of Springerville, Arizona. The field lies on the edge of the Holbrook basin, in the transition zone between the Colorado Plateau and Basin and Range tectonic provinces. CO_2 in the field is trapped in the Permian Supai Formation. The Supai Formation is predominantly fine-grained alluvial sandstone interbedded with siltstone, anhydrite, and dolomite. The reservoir is cut by a major northwest-southeast trending reverse fault. Cap rocks in the field are impermeable anhydrites, which vertically separate the CO_2 into multiple zones. The reservoir is relatively shallow at about 1500 feet. (Moore, et al., Arizona and New Mexico, Second Annual Conference on Carbon Sequestration. 2003) CO_2 in the structure is not in a supercritical state. Gas composition averages 93 percent CO_2, along with nitrogen, helium, methane, and argon. (National Academies, 2010)

As described in Stevens *et al.*, 2001, average reservoir porosity is 10 percent, and permeability varies widely, averaging 10 mD and resources are an estimated at 15 Tcf. Moore *et al*. estimated the porosity as 20 percent. (Moore, et al., Arizona and New Mexico, Second Annual Conference on Carbon Sequestration. 2003) The field was discovered in 1994. Ridgeway Petroleum Corporation drilled 15 wells in Arizona and six wells in New Mexico, which were subsequently shut in.

The company Kinder Morgan CO_2 purchased the field and is currently developing it with active drilling at this time. About 40 wells are completed, and a pipeline is planned running either northeast or directly east to tie with the current pipeline system delivering EOR CO_2 for Texas.

The route for the pipeline will be determined by the reserves proved up and the productive capacity of the field following the current drilling campaign. (Bradley, 2011)

2.2.9 Woodside, UT

The Woodside field is in Emery County, near the town of Woodside, Utah. It lies 25 miles to the southeast of Farnham anticline. The structure is a crescent-shaped, north-northeast to south-southwest trending, double-plunging anticline with 800 foot of closure and 12,800 acres within the closing contour. (Gilluly, 1929) CO_2 is found in the White Rim Sandstone at 3,500 feet at 32 percent concentration. (BLM, 2002)

2.3 Permian Basin

The location of the Permian basin, of which the Val Verde is a sub-basin, is shown in Exhibit 2-12. Exhibit 2-13 provides a geologic description for the Val Verde basin and Exhibit 2-14 presents its composite estimation of original GIIP. Exhibit 2-15 shows its recovery and access factors.

Exhibit 2-12 Location of the Permian Basin CO_2 discoveries

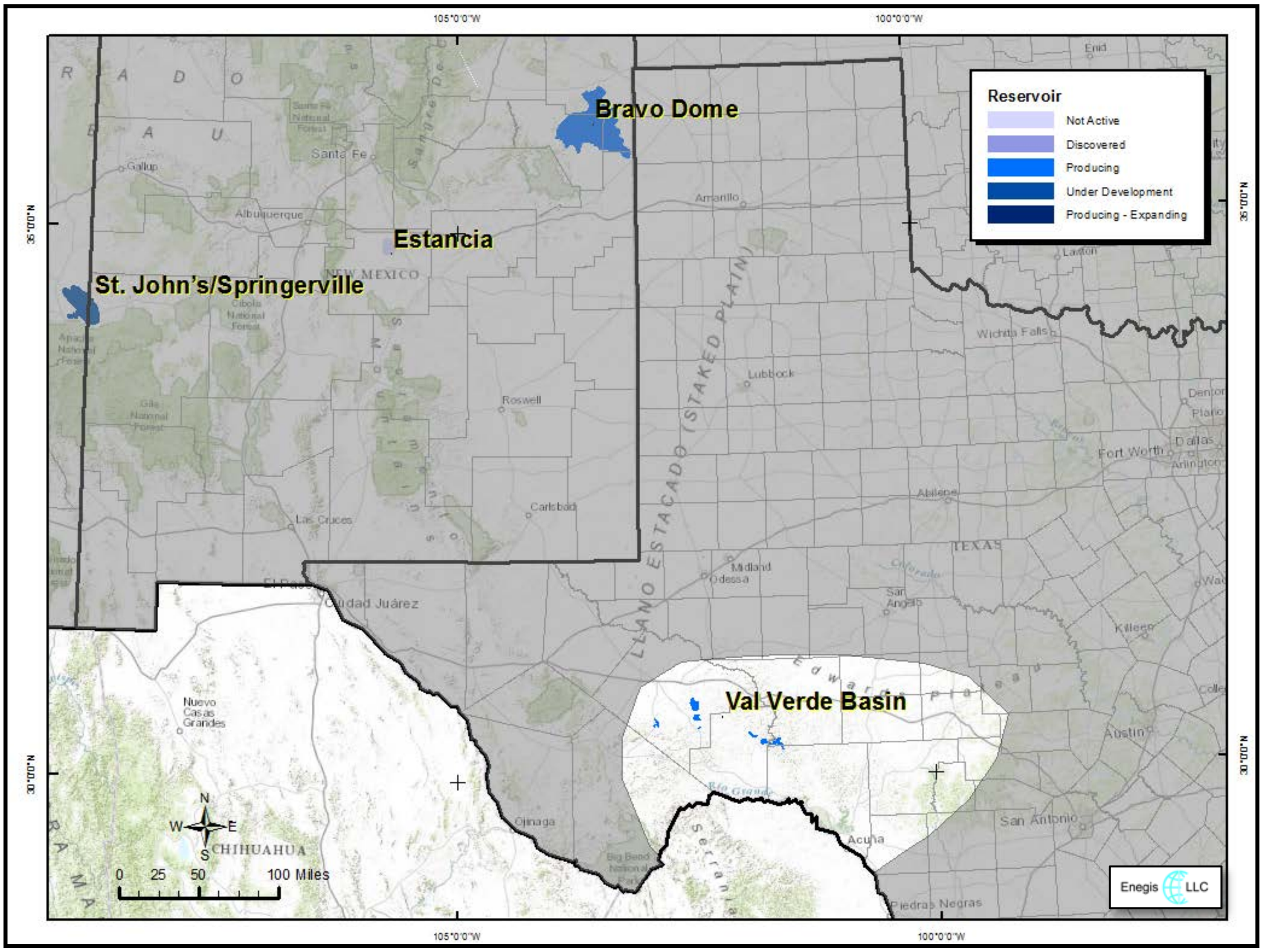


Exhibit 2-13 Geologic description and parameters of Permian Basin discoveries

CO_2 Assessment			Geologic Description	Depth	Net Pay	Fm Temp	Fm Pressure	Porosity
Structure or Field	State	Status		Feet	Feet	Deg F	Psi	%
Val Verde Basin	TX	Producing	Fault-bend folds in Marathon Thrust; Ellenburger Fm. Sealed by Simpson Shale and dolostone	13,561	640	218	5,872	4

Notes: GIIP=Gas Initially in Place, TRR=Technically Recoverable Resources, Tcf=Trillion cubic feet, Bcf=Billion cubic feet.
Conversion factor used=53 million tonnes CO_2 per Tcf.

Exhibit 2-14 GIIP estimation for Permian Basin discoveries

CO_2 Assessment			Area	CO_2 Conc	Connate Water Sat.	Depth	Volume Factor	CO_2 GIIP	CO_2 Density
Structure or Field	State	Status	Acres	%	%	Feet	Rscf/scf	10^6 Tonnes	Tonnes/ acre
Val Verde Basin	TX	Producing	69,677	40	20	13,561	0.004	7,361	105,647

Notes: GIIP=Gas Initially in Place, TRR=Technically Recoverable Resources, Tcf=Trillion cubic feet, Bcf=Billion cubic feet. Conversion factor used=53 million tonnes CO_2 per Tcf.

Exhibit 2-15 Recovery and access for Permian Basin discoveries

CO_2 Assessment			CO_2 GIIP	Recovery Factor	Access Factor	CO_2 TRR
Structure or Field	State	Status	10^6 Tonnes	%	%	10^6 Tonnes
Val Verde Basin	TX	Producing	7,361	70	95	4,895

2.3.1 Val Verde Basin, TX

The CO_2-bearing gas fields of the Val Verde basin are located in west Texas Terrell, Pecos, Crockett, and Val Verde counties, southeast of the city of Fort Stockton. The Val Verde basin is a foreland sub-basin of the west Permian basin. Structurally, it is situated between the Central basin platform to the south and the Marathon thrust belt to the north. (Ballentine *et al*., 2001) There are six fields (which contain varying amounts of CO_2) that produce from the upper and lower plates associated with the Marathon Thrust primarily from the Caballos and Ellenburger formations, respectively. (Boyce, 2009) Helium isotope analysis shows the CO_2 is magmatic in origin, associated with tectonic uplift to the north of the Val Verde basin. (Ballentine, 2001)

Oil operators in the Permian basin began CO_2 floods in the 1970s with CO_2 provided by natural gas processing plants in the Val Verde basin. A 16-inch, 220-mile SACROC pipeline has delivered 220 MMcfd to the Denver City, Texas CO_2 hub. (Holz, 1999)

CO_2-rich natural gas is produced from at least seven fields in the area, ostensibly from the Ellenburger, Simpson, and Woodford formations. The Puckett field is representative of the CO_2-producing fields. The field is a structural trap along a large faulted anticline that produces from the Ellenburger dolomites. Drill depths average 13,500 feet (Hester, 1959) with net thickness estimated at 650 feet. CO_2 concentrations range from 30 to 97 percent in each of the various fields. (Ballentine, 2001)

2.4 Other Discoveries

The location of the CO_2 discoveries outside of the Rocky Mountains, Colorado Plateau, and Permian Basin can be found in Exhibit 2-1. Exhibit 2-16 shows the geologic description of fields within these other discoveries. Exhibit 2-17 presents an estimation of original GIIP. Exhibit 2-18 shows their risk-weighting, recovery and access factors.

Exhibit 2-16 Geologic description and parameters of other discoveries

CO_2 Assessment			Geologic Description	Depth	Net Pay	Fm Temp	Fm Pressure	Porosity
Structure or Field	State	Status		Feet	Feet	Deg F	Psi	%
Imperial	CA	Inactive	Cenozoic SS reservoirs	591	230	245	339	12
Indian Creek	WV	Producing	Fractured-anticline; Tuscarora Formation	6,674	10	126	3,000	10
Jackson Dome	MS	Producing*	Anticlines and salt structures; Smackover LS, Norphlet Fm. Sealed by Jurassic mudstone.	15,500	185	339	7,000	13

Notes: GIIP=Gas Initially in Place, TRR=Technically Recoverable Resources, Tcf=Trillion cubic feet, Bcf=Billion cubic feet. Conversion factor used=53 million tonnes CO_2 per Tcf.

*Expanding relative to CO_2 development

Exhibit 2-17 GIIP estimation for other discoveries

CO_2 Assessment			Area	CO_2 Conc	Connate Water Sat.	Depth	Volume Factor	CO_2 GIIP	CO_2 Density
Structure or Field	State	Status	Acres	%	%	Feet	Rscf/scf	10^6 Tonnes	Tonnes/ acre
Indian Creek	WV	Producing	18,497	66	43	6,674	0.004	85	4,606
Imperial	CA	Inactive	1,725	95	20	591	0.010	158	91,371
Jackson Dome	MS	Producing*	90,000	90	20	15,500	0.003	24,245	269,387

Notes: GIIP=Gas Initially in Place, TRR=Technically Recoverable Resources, Tcf=Trillion cubic feet, Bcf=Billion cubic feet. Conversion factor used=53 million tonnes CO_2 per Tcf.

*Expanding relative to CO_2 development

Exhibit 2-18 Recovery and access for other discoveries

CO_2 Assessment			CO_2 GIIP	Recovery Factor	Access Factor	CO_2 TRR	Comments
Structure or Field	State	Status	10^6 Tonnes	%	%	10^6 Tonnes	
Imperial	CA	Inactive	158	65	80	82	Lower recovery due to discontinuous reservoirs with heterogeneous permeability. Access partially limited by Imperial National Wildlife Refuge
Indian Creek	WV	Producing	85	70	95	57	N/A
Jackson Dome	MS	Producing*	24,245	70	95	16,123	N/A

*Expanding relative to CO_2 development

2.4.1 Imperial, CA

The Imperial CO_2 field is located on the eastern shore of the Salton Sea, in Niland County, 18 miles north of Brawley, California. The field lies in the Salton basin and is part of the Salton Sea geothermal system. From 1934 to 1954, 650 million cubic feet (MMcf) of CO_2 was produced commercially for dry ice production. About 54 wells produced CO_2 from shallow (about 600 feet) sandstone reservoirs. (Muffler, 1968)

The geothermal system is entirely within the upper Cenozoic-aged sedimentary rocks of the Colorado River delta. Five small rhyolite domes are present in the area. Although $CO_2/^3He$ ratios are unavailable at this time, it is suspected that the Imperial CO_2 is magmatic in origin, derived from the underlying mantle. Liberated CO_2 then migrates upwards to the shallow reservoirs.

2.4.2 Indian Creek, WV

The Indian Creek field is in central Kanawha County, eight miles east of Charleston, West Virginia. The Indian Creek is one of six fields developed for natural gas in the fractured-anticline play of the Lower Silurian-aged Tuscarora Formation. The Tuscarora Formation, located broadly across Pennsylvania and West Virginia, comprises massive beds of brittle, highly fractured, quartz-cemented sandstone, separated by thin beds of shale. The Tuscarora Formation becomes increasingly marly and shaley from east to west, and ranges in thickness from less than 100 feet, in southwestern West Virginia, to more than 1,000 feet, in northeastern Pennsylvania. The formation is generally considered to be of fluvial and/or littoral origin. A petrologic study of a lower Tuscarora core from just east of the Indian Creek field concluded that it was deposited as a coastal sand in an environment characterized by high and fluctuating energy levels, shallow water, and high sedimentation rates. (Avary, 1996)

The Indian Creek field is located along the axis of the Warfield anticline. Warfield is the westernmost major anticline in West Virginia, and often considered to mark the southeastern boundary of the Rome trough. The anticline was sparsely drilled in the 1930s and 1940s, but significant development began in 1973 at a depth of about 6,700 feet with 10 feet of net pay. (Jenden, 1993) (Avary, 1996) The Tuscarora fields trap types are structural anticlines with fracture-enhanced porosity. The open fractures, in addition to intra- and inter-granular porosity, provide space for gas storage. The overlying Rose Hill Formation forms the Tuscarora reservoir seal.

CO_2 content ranges from 44 to 83 percent, averaging 65.8 percent (Hare, 1978) (Hamak, 1991) (Hamak, 1992) N_2 content averages 4 percent. (Hare, 1978) (Hamak, 1991) (Hamak, 1992) Despite the high CO_2 content in the produced natural gas, Indian Creek has proved to be a commercial success due to the nearby CO_2 market at Liquid Carbonic Carbon Dioxide Corporation, where the CO_2 is upgraded to food quality and sold. Initially, produced CO_2 was used for EOR, operated by Columbia Natural Resources in the nearby Granny Creek-Stocky field.

2.4.3 Jackson Dome, MS

Jackson Dome is located in the onshore Gulf Coast province, 15 miles east of Jackson, Mississippi. Jackson Dome is currently operated by Denbury Resources. An estimated 8 trillion cubic feet (Tcf) of economically recoverable CO_2 is present based on integrated production projections by Denbury. (Denbury, 2012) Current production has increased from about 30 MMcfd (Stevens, May 15-17, 2001) to over 1 Bcfd currently (Denbury, 2012). CO_2 is trapped in the Jurassic Norphlet and Smackover formations at an average depth of 17,500 feet based on Zimmerman (Zimmerman, 1979) and DiPietro *et al.* (DiPietro, 2012)

At Jackson Dome, the Smackover Formation is composed of brown to grey limestones and dolomites with interbedded dolomitic sands, typically with a porous dolomitic basal sand member. Gross thickness of the Smackover Formation in the study area is estimated to be from 1,000 to 2,000 feet. Smackover porosity and permeability are highly varied in the carbonate section, ranging from porous oolitic, to intergranular, to vuggy and fractured. The Norphlet Formation is described as a sequence of primarily fine-grained eolian sands. Gross thickness for the Norphlet is a minimum of 300 feet. These formations are overpressured, indicating an effective caprock seal. (Stevens, May 15-17, 2001)

CO_2 concentrations range from 65 to 99.6 percent. Jurassic sediments in the area have tested sour gas since exploration began in the 1950s. H_2S is a common hazard, averaging 5 percent but ranging as high as 35 percent. (Zimmerman, 1979) For purposes of this analysis, the sulfur derived from production at Jackson Dome is assumed to be marketable.

3 Resource Estimation Methodology

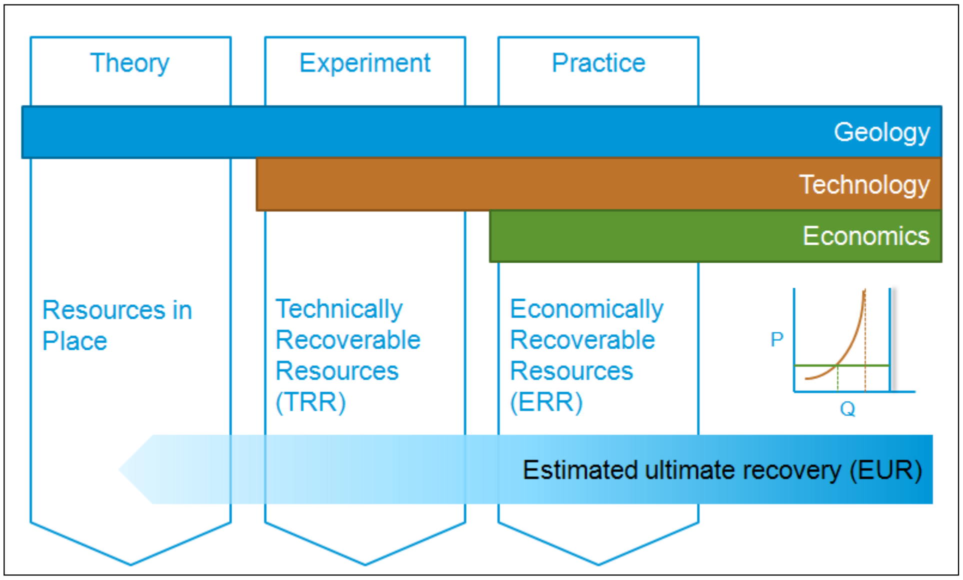
Most CO_2 deposits discovered to date in the U.S. have been the by-product of exploration efforts for hydrocarbons. The methodology presented here for evaluating the recoverability of CO_2 resources is based on that developed for the assessment of unconventional natural gas resources. Method for this analysis is deterministic, based on average properties for parameters (analogous to P_{50} estimates). The methodology comprises three steps that make up a resources hierarchy:

1. **Gas-initially-in-place (GIIP)**
2. **Technically recoverable resources (TRR)—**a subset of GIIP comprising that portion that can be recovered by technical means without explicit consideration of economics

3. **Economically recoverable resources (ERR)**—a subset of TRR that meets economic criteria for potential production and are amenable for development into reserves[1]

Exhibit 3-1 shows the relative relationships for defining resource potential. Technically recoverable resources can be considered analogous to so-called 3P estimates (proven, probable and possible) used in industry.

Exhibit 3-1 Schematic depiction of methodology for defining resource potential



Source: EIA (EIA, 2013)

[1] This analysis does not assess reserves in a Securities and Exchange Commission (SEC) context.

3.1 CO_2 Resources Evaluation Analytical Model

Using the project dataset culled from a survey of public literature, a spreadsheet analytical tool was created to develop resource estimations. Labeled the CO_2 Resources Evaluation Analytical Model (CREAM), the tool is a Visual Basic for Applications (VBA)-coded Microsoft Excel spreadsheet driven by input parameters for the GIIP equation, and algorithms for TRR and ERR. An electronic copy of CREAM (with references only) accompanies this report; input parameters are documented as to literature source, including page number where practicable to maximize transparency. The intention is to provide the reader with an ability to reproduce the analysis. CREAM is documented in comments appended to data cells within the model, an example of which is shown in Exhibit 3-2.

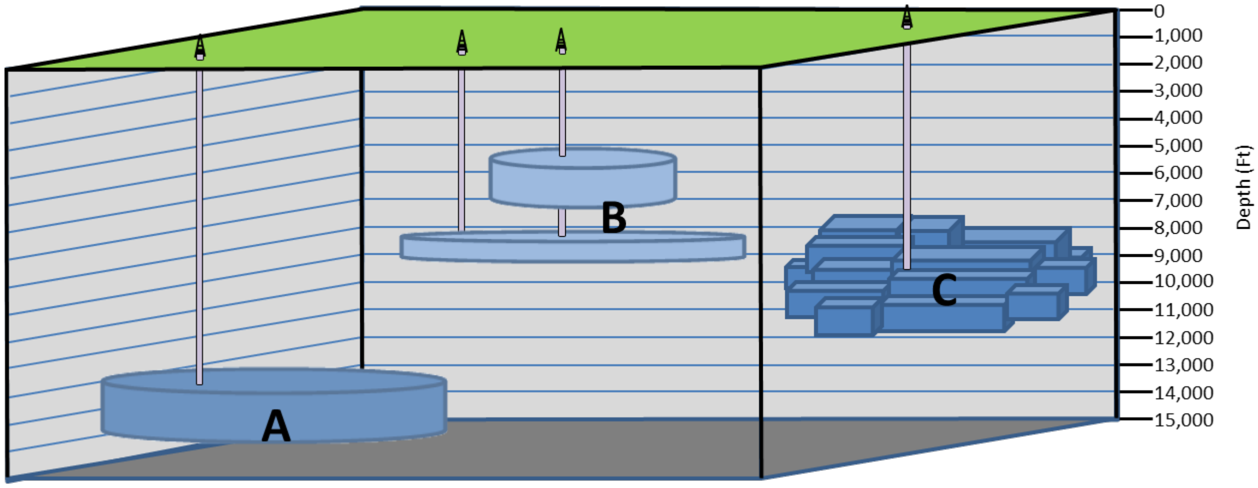
Exhibit 3-2 Illustration of documentation of parameters in CREAM

Area or Field	Reservoir	State	Region	Status	Area	Net Thick	ϕ
					Acres	Ft	%
Imperial	Cenozoic Ss	CA	Other	Inactive	1,725	230	12%
Doe Canyon	Leadville, Ouray	CO	Colorado Plateau	Under development	82,078	60	10%
McCallum	Dakota Ss, Lakota Ss	CO	Rocky Mountains	Producing	15,250	100	20%
McElmo Dome	Leadville, Elbert	CO, UT	Colorado Plateau	Producing (expanding)*	201,500	95	12%
Oakdale	Dakota, Entrada, dike	CO	Rocky Mountains	Discovered	3,400	250	19%
Sheep Mountain	Dakota, Entrada	CO	Rocky Mountains	Producing	12,200	145	20%
Jackson Dome	Smackover, Norphlet Fms	MS	Other	Producing (expanding)*	[illegible]	[illegible]	13%
Kevin Dome	Common Deperow Fm (Uppr & Lwr)	MT	Rocky Mountains	Producing	[illegible]	[illegible]	9%
Kevin Dome	Unique Lower Deperow Fm	MT	Rocky Mountains	Producing	[illegible]	[illegible]	9%
Bravo Dome	Yeso Fm-Tubb Ss Mem	NM	Rocky Mountains	Under development	[illegible]	[illegible]	20%
Des Moines	Abo Fm	NM	Rocky Mountains	Inactive	[illegible]	[illegible]	20%
Estancia	Sandia Fm	NM	Colorado Plateau	Inactive	47,750	65	14%

Jeffrey Eppink:
Spangler et al., 2012, Table 3

Where adequate map data exist (such as structural maps for BPLB), CREAM interacts with these data using a GIS, as is the case at BPLB. Three basic scenarios were encountered, based on the amount of available data. As shown in Exhibit 3-3 (A), most reservoirs were modeled as single formation, with uniform depth, and uniform thickness. In fields with stacked reservoirs such as Kevin Dome and shown in Exhibit 3-3 (B), multiple formations were modeled with unique, uniform depths and thicknesses. Single completions were modeled in areas with only one formation and multiple completions were modeled in areas of geographic coincidence. Finally, in BPLB, a geologic structure map was used to obtain a more-detailed reservoir surface, shown in Exhibit 3-3 (C). This more-precise depth data could be applied to other basins and integrated with an isopach for more precise thickness data.

Exhibit 3-3 GIS methodologies for modeling reservoirs at depth



For additional parameters, such as water saturation, initial gas formation volume factor, permeability, and porosity, values were obtained from literature, or estimates were used. The parameters were assessed so as to determine representative values (average or mean) for input into the deterministic analysis. The fields were evaluated at the most disaggregated level that data allow (i.e., by field or by reservoir). Generally, analysis was conducted on a field basis given the state of available public-domain information. In some cases, multiple reservoirs exist within individual fields, each of which was examined separately (e.g., for the Escalante field). If partial data were available by reservoir, average properties were used for analysis on a field-level basis.

When examining this report, the reader will need to differentiate between natural gas (comprising methane, carbon dioxide, nitrogen, etc.) and CO_2, where the exhibits are annotated accordingly. Because CO_2 ranges from 20 to 100 percent in the fields assessed, its content can make a significant difference when examining outputs.

3.2 Gas-Initially-in-Place

The volumetric calculation of GIIP is an extension of the computation of effective pore volume that considers the effect of gas expansion. Equation 1 was used to calculate GIIP.

Equation 1

$$GIIP = \frac{C_{Vol} \cdot A \cdot H \cdot \phi(1 - Swc)}{B_{gi}} \cdot \varsigma$$

Where:

$GIIP$ = Gas-initially-in-place, in standard cubic feet (scf) for CO_2

A = Area (acres)

H = Pay thickness (feet)

Φ = Porosity (fraction)

Swc = Connate water saturation (fraction)

Bgi = Initial gas formation volume factor in reservoir ft^3 per scf (reservoir cubic feet (rcf)/scf)

C_{Vol} = A volumetric constant, 43560 ft^3/ ac-feet (cubic foot/acre-foot)

ς = CO_2 concentration (volumetric percent)

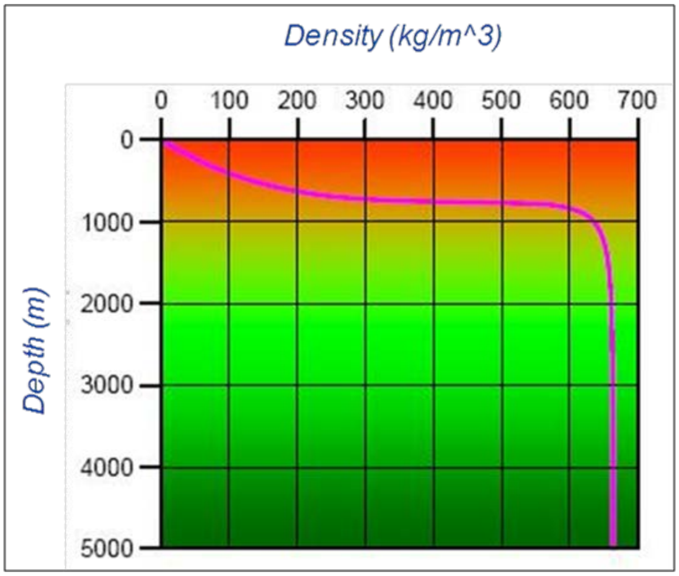
3.2.1 Supercritical CO_2

Supercritical CO_2 exits in a fluid state of matter that has physical properties of both gases and liquids. Above critical temperature (88.0 °F) and critical pressure (72.9 atmospheres), supercritical CO_2 will expand to fill available volume, but with density like that of a liquid. At depths below about 2,500 feet, hydrostatic pressure greatly reduces the volume of CO_2 compared to surface conditions. As shown in Exhibit 3-4, as further depth, pressure, and temperature continue to increase, the density of the CO_2 remains nearly the same.

Estimates of CO_2 volumes are highly dependent on whether or not the gas is supercritical. This complexity is integrated into the analysis conducted in this report. Exhibit 3-5 shows the distribution of fields and reservoirs relative to the phase of the CO_2 contained within them. The exhibit shows the downhole temperature and pressure conditions of the discovered subsurface CO_2 reservoirs in the U.S. overlain with a phase change curve for pure CO_2. The phase change curve is not precisely relevant because of the other components in the natural gas, but it gives a general indication that most of the reservoirs are well into the supercritical region. Bravo and St. Johns are the two exceptions.

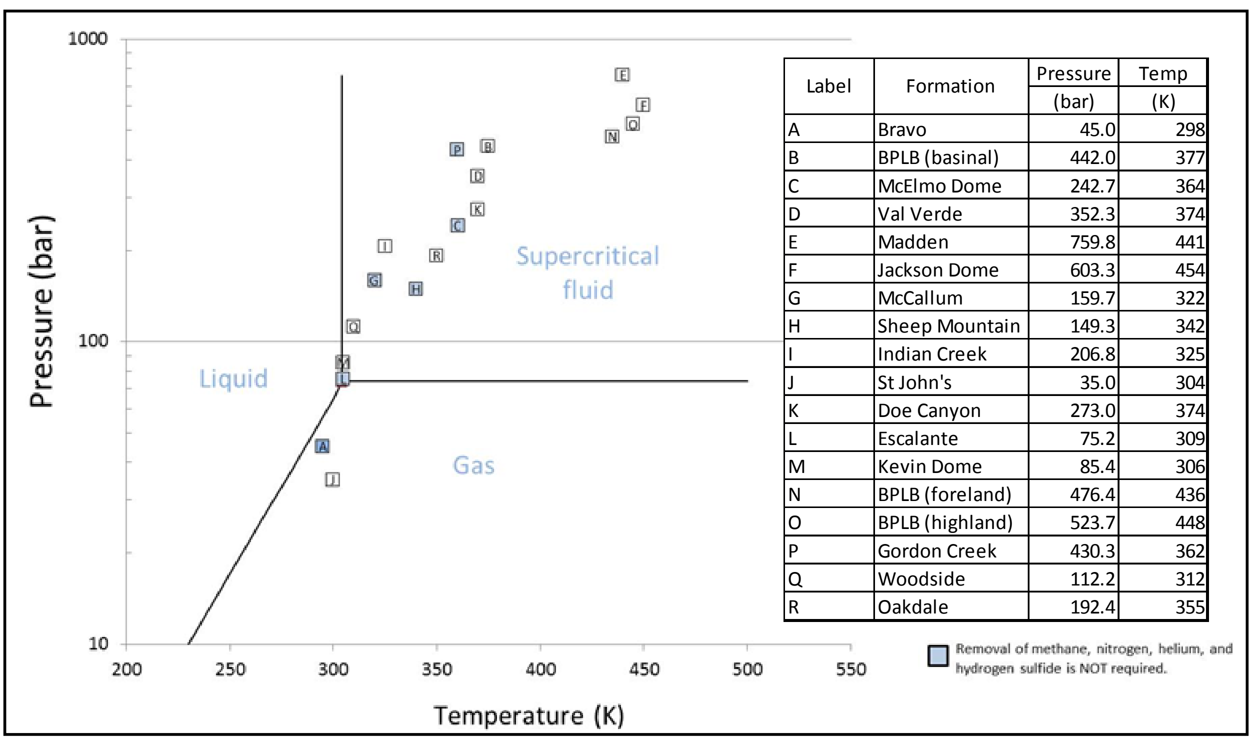
Exhibit 3-6 shows well head pressure for the same reservoirs. In this study, an estimated pressure drop of 0.15 pounds per square inch (Psi) per foot has been applied. (Lu, 2008) The CO_2-containing fluid will tend to get cooler as it comes up the well bore due to heat transfer to the surrounding earth, which is cooler near the surface. With a lack of good information on temperature gradient an isothermal well bore is assumed. The Escalante, Kevin and Woodside fields are shown as transitioning to gaseous phase. In practice, this would be avoided. Other fields are safely above the phase change pressure.

Exhibit 3-4 CO_2 (100 percent concentration)



Source: ©2003 BGR (BGR, 2003)

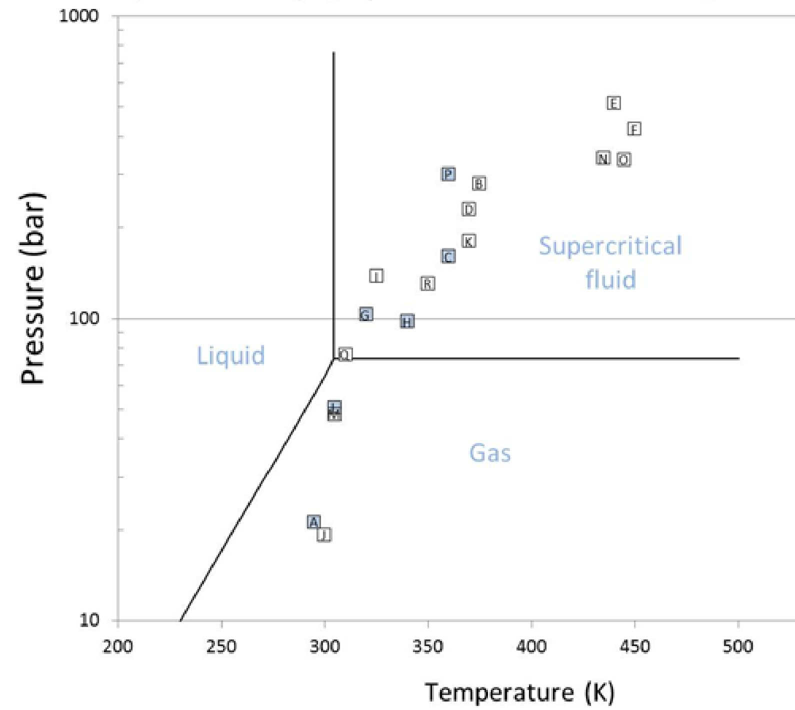
Exhibit 3-5 Downhole pressure, temperature and CO_2 phase



Label	Formation	Pressure (bar)	Temp (K)
A	Bravo	45.0	298
B	BPLB (basinal)	442.0	377
C	McElmo Dome	242.7	364
D	Val Verde	352.3	374
E	Madden	759.8	441
F	Jackson Dome	603.3	454
G	McCallum	159.7	322
H	Sheep Mountain	149.3	342
I	Indian Creek	206.8	325
J	St John's	35.0	304
K	Doe Canyon	273.0	374
L	Escalante	75.2	309
M	Kevin Dome	85.4	306
N	BPLB (foreland)	476.4	436
O	BPLB (highland)	523.7	448
P	Gordon Creek	430.3	362
Q	Woodside	112.2	312
R	Oakdale	192.4	355

Source: NETL

Exhibit 3-6 Wellhead pressure, temperature and CO_2 phase



Label	Formation	Pressure (bar)	Temp (K)
A	Bravo	21.2	298
B	BPLB (basinal)	279.8	377
C	McElmo Dome	160.0	364
D	Val Verde	230.2	374
E	Madden	514.7	441
F	Jackson Dome	422.3	454
G	McCallum	102.8	322
H	Sheep Mountain	97.6	342
I	Indian Creek	137.8	325
J	St John's	19.2	304
K	Doe Canyon	180.0	374
L	Escalante	50.7	309
M	Kevin Dome	48.2	306
N	BPLB (foreland)	338.3	436
O	BPLB (highland)	335.9	448
P	Gordon Creek	300.3	362
Q	Woodside	76.0	312
R	Oakdale	130.3	355

Source: NETL

3.2.2 Rock Volumes

For determination of area and rock volumes, GIS structural maps of reservoirs or surface expressions of field boundaries were used to estimate the geographic footprint of individual reservoirs. Net thickness was either gleaned from literature or inferred from gross thickness and net-to-gross ratios to determine rock volumes that contain CO_2.

It is recognized that bulk porosity is a function of matrix and fracture porosity (porosities which were investigated from the literature). Fractures provide both gas storage capacity and permeability, and can be the determining factor for the effectiveness of porosity in the system. Fracture porosity is fractal and can be associated with large (regional) faults, seismic, and well-bore scales. Analytically, if mapped-fault geometries were available, the probability for fracturing associated with proximity to mapped faults was postulated to assess fracture porosity in a GIS survey of each of the fields.

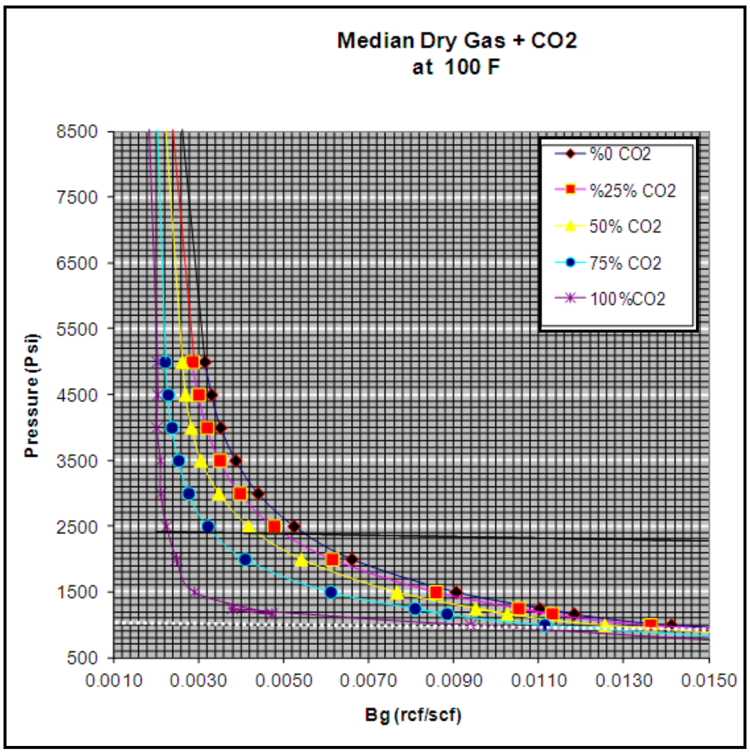
3.2.3 Formation Volume Factor

Ideally, in order to determine the initial gas formation volume factor (Bgi) as a function of reservoir pressure, it is necessary to calculate additive volume gas compressibility factor (Z) as a function of reservoir pressure (P) to correct for the deviation from perfect gas law due to high CO_2 concentrations. Functions are then generated and used to obtain values of Bgi at estimated initial reservoir pressure and at abandonment pressure.

Bgi is highly dependent on temperature and pressure. Reservoir temperatures (original conditions) were determined using Southern Methodist University (SMU) Geothermal

Laboratory Temperature-at-depth maps (SMU, undated) or, on some occasions where available, published literature. Pressure was determined using hydrostatic gradients (0.433 to 0.481 Psi/feet) dependent on geology and rare published values. Drill depth was then used to determine reservoir pressure. Bgi then was determined following the methodology of Adisoemerta *et al.*, (Adisoemerta, et al., 2004) published by the Society of Petroleum Engineers. That publication documents performed compressibility factor measurements at various compositions of CO_2 with hydrocarbon gas mixtures. Various temperatures and pressures, representative of depleted reservoirs, were assessed to analyze the phase behavior encountered in gas reservoirs. The measurements of compressibility factors for CO_2-hydrocarbon mixtures were performed at specified temperatures for various pressures on median gas compositions. Based on that publication, a family of pressure-Bgi curves was developed by temperature for various concentrations of CO_2, an example of which is shown in Exhibit 3-7. Reservoir-specific Bgi values were then manually interpolated.

Exhibit 3-7 Bgi as a function of pressure



3.2.4 Water Saturation

Data on water saturation were used where available. Analogs were used in absence of reservoir-specific data. Generally, water saturation was estimated to be 20 percent.

3.2.5 CO_2 Concentration

CO_2 concentration was mapped where data allowed. Published estimates were used for most fields. Analogs were used otherwise.

3.2.6 GIIP Calibration and Estimation

Once the parameters were established in CREAM, computer code was developed to calculate the GIIP. GIIP was calculated by formation according to spatial distribution where data were available. The Tab "CREAM_GIIP" presents the data and calculated values.

Fields were examined at the most disaggregated level of information available for the fields. They were run by reservoir where data were obtainable (as in the case of Escalante field) or as a series of polygons where sufficient map data existed to overlay them (e.g., BPLB) to determine intersections comprising discrete GIS polygons. Otherwise, fields were examined as a single reservoir. Ideally, it is beneficial to disaggregated fields at the highest level; unfortunately, these data are not generally available in the public domain. In Appendix A2, Exhibit A2-1 shows the GIIP by field, or respective reservoir where data are available. The fields in Exhibit A2-1 are ordered alphabetically by state as they were input into CREAM.

3.3 Technically Recoverable Resources

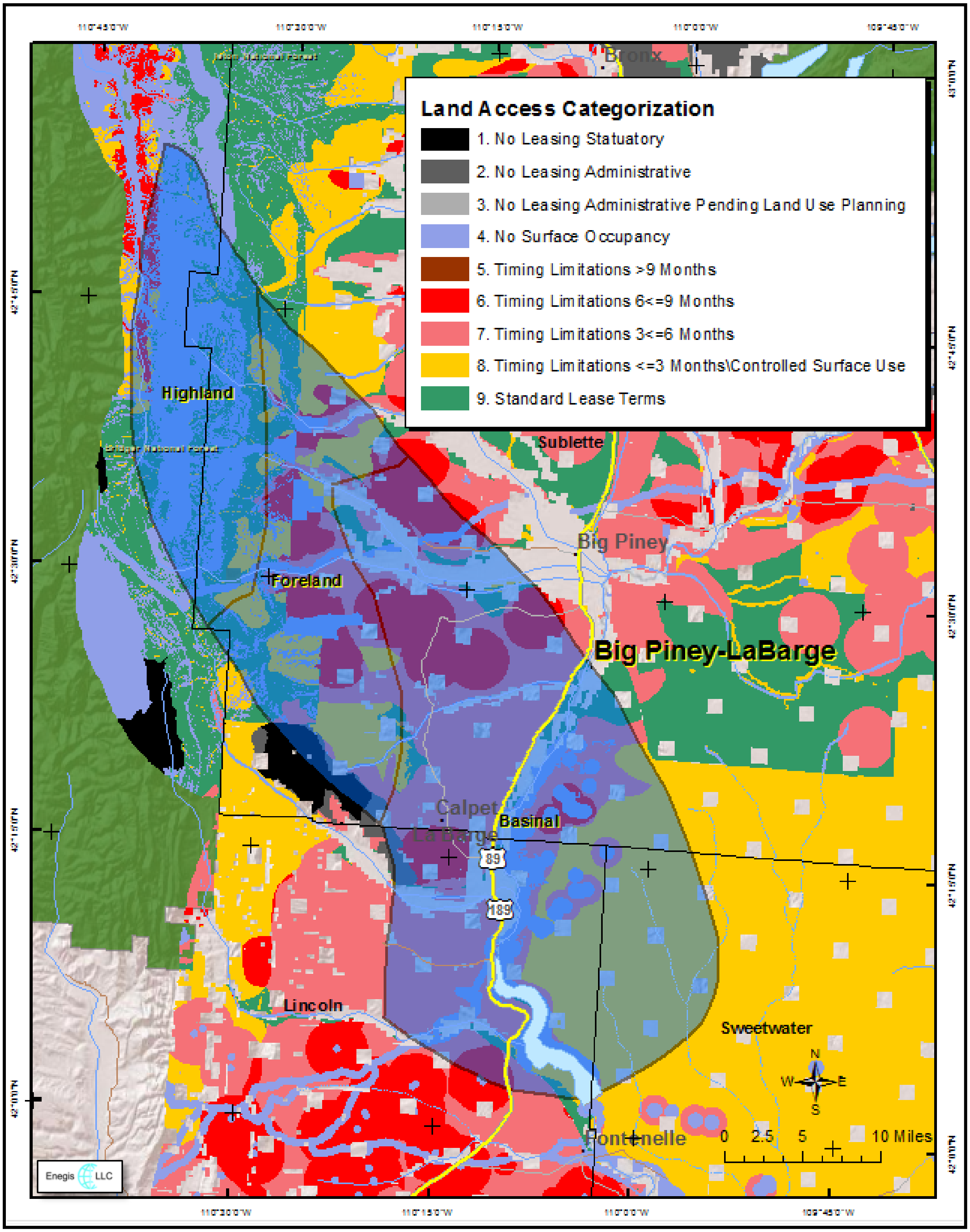
Technically Recoverable Resources, as a subset of GIIP, were estimated as the next step. TRR is directly influenced by permeability, which can differ among lithologies and depositional environments. A Recovery Factor (RF) was determined, which represents the portion of GIIP that can be technically recovered, where the RF is multiplied against the GIIP to determine TRR. Recovery Factors are generally assumed to be 70 percent and commonly range from 60 to 80 percent. They are adjusted by reservoir in consideration of its geological context.

Recovery factors for each field or reservoir are based on using literature (e.g., Zimmerman, (Zimmerman, 1979) and ETSAP (ETSAP, 2010)) and Enegis' prior experience. Enegis has conducted, in studies elsewhere, comparisons of Estimated Ultimate Recovery (EUR) to in-place resources and in consideration of connectivity and reservoir rock type (i.e., behavior as a function of lithologic type and in consideration of naturally fracturing, where connectivity can be higher leading to increased technical recovery). In addition, the International Energy Agency (IEA) provides storage coefficients for CO_2 (which, in turn, are derived from parameters including relative permeability, vertical to horizontal permeability, anisotropy and injectability) for various lithologies. (IEA, 2009) This work shows that dolomites have the highest coefficients flowed by clastics and limestones.

An important consideration in resource development, which was included in TRR, is that of accessible resources (areas where drilling is able to occur as a function of leasing stipulations) determined using generalized results from the Energy Policy and Conservation Act inventory. (BLM, 2011) Accessible resources generally range from 20 to 95 percent of TRR. An example of accessible resources determination is shown in Exhibit 3-8, which displays BPLB basinal, foreland, and highland areas that were estimated to have Access Factors (AF) of 85, 80, and 30 percent accessible, respectively.

Equation 2 shows the relationship between GIIP, RF and AF to determine TRR.

Exhibit 3-8 Big Piney-LaBarge land access categorization



Equation 2

$$TRR = GIIP * RF * AF$$

Where:

$GIIP$ = Gas-initially-in-place, in scf

RF = Recovery Factor (fraction)

AF = Access Factor (fraction)

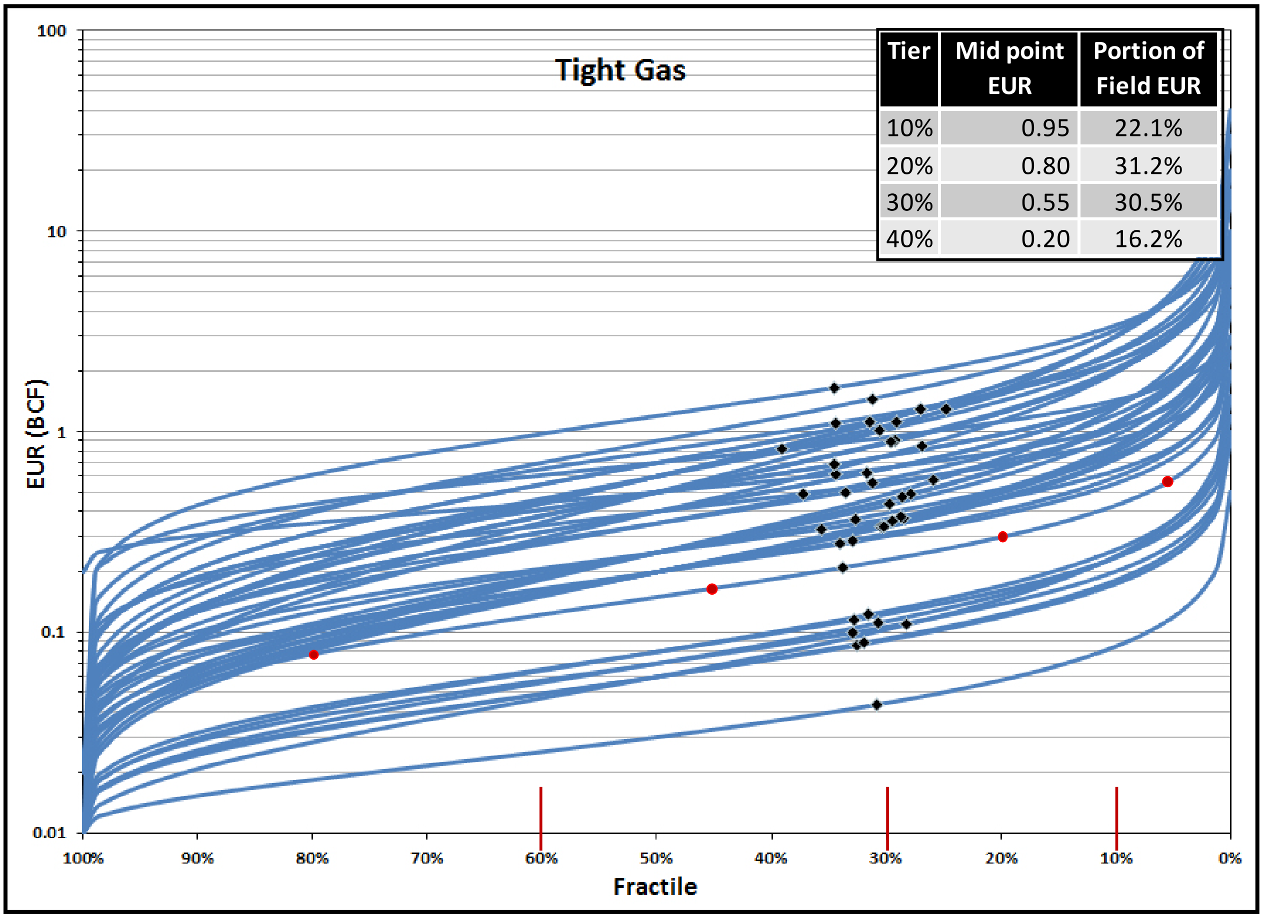
After establishing the volume of TTR, CREAM determines how it can be developed using assumed well spacing and gradation of EUR into "tiers" as a surrogate for discriminating well locations based on productivity. The total number of possible wells that could be drilled in a particular field, and therefore access TRR, is dependent upon the field area and the well spacing. CREAM assumed a spacing of 640 acres per well. A success rate for drilling of 85 percent was used for all fields.

Average EURs were established by dividing the accessible TRR by the number of wells that could be drilled within a field. Subsequently, an EUR distribution of prospectivity was assumed. The tiers in the EUR distribution are based on experience in examining plays where sufficient drilling has occurred to allow for a breakdown of the well population into subgroups. Each subgroup then can be examined separately, and serves to capture recovery heterogeneity as a function of such features as geology and sweet spots. The tiers are as follows:

- 10 percent tier—high value EUR well locations
- 20 percent tier—value EUR well locations
- 30 percent tier—slightly above average value EUR well locations
- 40 percent tier—below average value EUR well locations

The relative EUR associated with each tier was established building upon work performed by the U.S. Geological Survey (USGS) that addressed the variability of distributions of EURs for unconventional oil and gas resources in the United States. (USGS, 2012) Particularly, EURs were calculated relative to each tier for each of the Assessment Units (AU) set forth by USGS. Subsequently, median EURs were calculated for each tier from all the AUs, and used as a proxy (Exhibit 3-9).

Exhibit 3-9 Determination of tier EURs



Source: USGS (USGS, 2012)

The economic analysis was conducted by field or by individual reservoir within a larger field where data permitted (e.g., Big Piney-LaBarge, Val Verde, Escalante, Kevin Dome and Gordon Creek). We further divided each field/reservoir into four productivity tiers. This is based on experience in the oil and gas industry with "sweet spots." The underlying assumption is that generally developers will be able to find the sweet spots and develop the tiers sequentially. The relative values for EUR were drawn from data for unconventional oil and gas reservoirs and are shown in Exhibit 3-10. For example, the top tier represents 10 percent of the reservoir area but provides 22 percent of the total expected ultimate recovery. The well EUR adjustment factor for each tier equals the percent total EUR divided by the portion of the reservoir in the tier.

Exhibit 3-10 Factors applied to model tiers of well productivity

Tier	Portion of reservoir	% of total EUR	Well EUR adjustment factor
1st	10	22	2.20
2nd	20	31	1.55
3rd	30	31	1.03
4th	40	16	0.41

Equation 3 is applied to estimated CO_2 production per well (P_T).

Equation 3

$$P_T = (G_R / A_R) * S_F * E_F * F_T$$

Where

P_T – production per well for the tier (Tcf/well over a 30-year life)

G_R - GIIP for the reservoir (Tcf)

A_R - Area of the reservoir (acres)

S_F - Well spacing for the field (acres per well)

E_F - Estimated ultimate recovery for the field (% CO_2 IIP)

F_T - Well EUR adjustment factor for the tier (Exhibit 3-10)

In CREAM, the TRR parameters and results are shown on the Tab "CREAM_TRR." In Appendix A2, shows the TRR by field, which are ordered alphabetically by state as they were input into CREAM.

3.4 Economically Recoverable Resources

Economically Recoverable Resources, as a subset of TRR, are estimated by determining project economics based upon estimated drilling, completion, processing, and ancillary costs. Standardized costs were developed, but applied according to factors such as the depth of the reservoir, topography, geographic location, and CO_2 price. CREAM uses a net present value (NPV) analysis to discriminate resources as economic or uneconomic. NETL indicated that the CO_2 price to be used as $20/tonne, or $1.06/thousand cubic feet (Mcf). This price is considered to occur at the lease-line and does not consider pipeline costs for transportation to market.

CREAM runs the analysis per tier by reservoir, reading reservoir parameters and posting to a worksheet NPV analysis, which cycles through to return the NPV and associated ERR values. In the NPV analysis, the first year (year zero) is considered to be for lease acquisition and drilling, with production scheduled over 30 years using 6 percent annual decline. CO_2 revenue is posted as a function of CO_2 price and production volume. A royalty was established at an assumed rate of 12.5 percent, which is that charged on federal lands.

Drilling capital expense (CAPEX) is determined as a function of drill depth based on regional $/foot data from the Energy Information Administration (EIA). (EIA, 2013) Drilling success rate, assumed to be 85 percent, established a 15-percent dry-hole burden. CAPEX costs were also considered for gathering lines based on Interstate Natural Gas Association of America (INGAA) (INGAA, 2010) (INGAA, 2011) and EIA data, (EIA, 2012) as well as dehydration costs based on Environmental Protection Agency (EPA) (EPA, 2008) data. Operating expense (OPEX) costs were considered for dehydration based on EPA data, (EPA, 2008) as well as monthly well and lease costs, such as electricity and maintenance.

Compression costs are significant in CO_2 field development. Suction (inlet) compressor pressures are estimated at original reservoir pressure, reservoir pressure decline, head pressure loss and gathering line loss. Based on research as documented in CREAM, a pressure was established for each reservoir. Reservoir pressure declines are considered as a function of EUR depletion over the productive life of a reservoir based on the portion of the EUR extracted relative to the total resource in a given productive year. Head pressure loss is calculated by considering the depth of the formation and a gradient of 0.15 Psi/foot. (Lu, 2008) Gathering line loss is estimated to be 250 Psi based on experience. (Fox, 2013) For reservoirs at high pressures, a suction pressure of 600 Psi was assumed as the optimum for removing (“knocking out”) water from the CO_2. (Fox, 2013) As a simplification, for low pressure reservoirs, a maximum initial suction of 50 Psi was assumed. In addition, if the field undergoes processing for non-CO_2 gases, e.g., as occurs at BPLB, a suction pressure of 50 Psi is assumed. (Fox, 2013) (Denbury, July 2013) The pipeline pressure requirement is 2,200 Psi. (INGAA, 2010) Compression costs are calculated at a rate of 0.000237 $/Mcf/deltaPsi based on Summers, which calculated a cost of $9.95/tonne assuming an inlet pressure of 1.6 bars (see Equation). (Summers, 2013, in publication)

Equation 4

$$0.000237 = \$9.95/tonne * 0.053 \frac{mtCO2}{Mcf} / DeltaPsi$$

Where:

$DeltaPsi$ = Outlet-inlet pressure

The economic impact of other co-mingled natural gases is considered. If methane is present, it is assumed to be produced at $5.00 per Mcf at a 10 percent margin. The margin was set to accommodate increased costs associated with separation of methane. $5.00 per Mcf was chosen based on the long-term projections of prices by EIA. (EIA, 2013) If N_2 is present in a field, CREAM considers concentrations greater than 4 percent beyond pipeline specifications and scrubs it at a cost of $0.41 to $0.90/Mcf (levelized based on costs presented in Mitariten (Mitaritan, 2009)) dependent upon well production rates. If H_2S is present, CREAM first scrubs to a pipeline specification of 35 parts per million (ppm) at a cost of $6.75/Mcf (levelized based on costs presented in Cline *et al.* (Cline, 2012)). It was confirmed that sulfur produced at the Lost Cabin facility, Madden field, is currently being sold into the local fertilizer market. (ConocoPhillips, undated) CREAM assumes that sulfur produced at Jackson Dome will likewise be sold at a price of $142 per ton. (Feytis, 2012)

Earnings before taxes (EBT) is established as a cash flow sum by year over the presumed 30-year life of production. Taxes are assessed at a 35 percent rate to include federal and state income, severance, and ad valorem taxes. A discount rate of 12 percent is assumed.

The presence of methane or marketable sulfur can enhance the economics of development of a deposit, although, especially for methane, the more fundamental question can be whether the deposit is being developed for methane itself with CO_2 development as ancillary (as in the case of the Madden field). Further, if the sulfur is not sold, its processing and handling can become a significant cost item. If sulfur is not sold, CREAM assumes that reinjection will cost 75 percent of sulfur processing costs. Helium was also considered in the economic analysis for reservoirs where its content was 0.2 percent of greater. The cost for helium production is based on Bureau of Land Management (BLM) (BLM, 2013) and a generalized helium price ($125/Mcf) on Washington Post. (Washington Post, 2012)

CREAM assesses NPV by tier (10, 20, 30, and 40 percent). Reservoir NPV, and thereby ERR, are determined by the dry hole burden times the number of wells, times the EUR (by tier), times the CO_2 concentration. CREAM assumes that the drilling that occurs in the fields is selective, i.e., it assumes that there is “learning by doing” where industry, by knowledge and insight, avoids drilling negative NPV wells. The results are calculated in the spreadsheet via a macro and then posted to the CREAM results section. (See the Tabs “CREAM_ERR_R” where *all* NPVs are posted and “CREAM_ERR_S” where *positive* NPVs values only are posted. The positive NPVs are assumed to be what industry is able to focus upon given learning feedback.) In Appendix A2, Exhibit A2-3 and Exhibit A2-4 show the ERR for CO_2 by field (ordered alphabetically by state as they were input into CREAM). Finally, estimates of already produced CO_2 in each of the fields were determined (Exhibit 3-11) and subtracted from ERR to determine remaining or net ERR.

Exhibit 3-11 Produced CO_2

Structure or Field	Produced CO_2 (Bcf)
McElmo Dome	7,200
Bravo Dome	2,900
Val Verde Basin	1,500
Jackson Dome	1,800
Big Piney-LaBarge Basinal	1,500
Big Piney-LaBarge Foreland	1,500
Sheep Mountain	1,300
McCallum	871
Doe Canyon	90
St. Johns/Springerville	90
Madden	80
Des Moines	20

Structure or Field	Produced CO_2 (Bcf)
Indian Creek	20
Estancia	14
Oakdale	5
Farnham Anticline	5
Escalante Anticline	1
Gordon Creek	1
Imperial	1
Kevin Dome	-
Lisbon	-
Woodside	-
Big Piney-LaBarge Highland	-
Total	18,851

Region Coding: Colorado Plateau, Rocky Mountains, Permian Basin, Other

4 Results

4.1 Results and Discussion

The results of the assessment from CREAM, where past production has been subtracted to yield net accessible ERR, are presented by field in Exhibit 4-1 by CO_2-EOR market system. Results show that total GIIP CO_2 resources are about 311 Tcf (16.5 billion tonnes) of which approximately 168 Tcf (9.0 billion tonnes) may be technically recoverable and 96 Tcf (5.1 billion tonnes) economically recoverable (inclusive of past production). The Rocky Mountain region contains the largest volumes of CO_2. The bulk of current EOR production is in Texas with growing demand from oil fields in Colorado, Wyoming, and Montana.

Exhibit 4-1 Subsurface sources of CO_2 in the U.S.

CO_2 EOR System	Structure or Field	State	2013 Production MMscfd	Rock type	Depth	Area	Pay	Por	FVF	Rec	Access	Gas Components, volume %					Resource Estimates, Tcf				
					000 ft	000 acres	ft	%	rcf/ (000 scf)	%	%	CO_2	CH_4	N_2	He	H_2S	GIIP	TRR	Gross ERR	Cumm Prdn	Net ERR
Permian Basin	McElmo	CO, UT	1,135	LS	8.0	202	95	12	2.6	70	65	98	0	2	0.07	--	30	14	12	7.2	4.4
	St. Johns	NM, AZ	--	SS	1.5	220	75	15	9.0	70	80	93	--	4	0.60	--	8.9	5.0	4.3	0.09	4.2
	Bravo Dome	NM	405	SS	2.6	700	125	20	16.0	65	90	97	--	--	0.02	--	23	14	5.4	2.9	2.5
	Doe Canyon	CO	105	LS	9.0	82	60	10	3.2	70	75	95	--	--	--	--	5.1	2.7	1.1	0.09	1.0
	Val Verde	TX	165	Dol	14	70	650	4	3.5	70	95	42	58	--	0.01	--	7.3	4.9	1.6	1.5	0.1
	Oakdale	CO	--	SS	6.0	3	250	19	3.5	65	80	72	28	--	0.03	--	1.2	0.6	0.5	0.01	0.5
	Sheep	CO	45	SS	5.0	12	145	20	3.9	65	80	97	1	--	0.03	--	3.1	1.6	1.4	1.3	0.1
	Lisbon	UT	--	LS	10	3	75	12	3.8	70	85	90	--	--	--	--	0.2	0.1	--	--	--
															Subtotal		79	43	26	13	13
Rocky Mountain	BPLB Basinal	WY	108	SS, dol	16	138	275	9	2.8	70	85	85	9	3	0.50	2.4	113	67	45	1.5	43.2
	BPLB Foreland	WY	107	SS, dol	16	125	275	9	3.2	70	80	74	15	6	0.50	4.2	30	17	7.2	1.5	5.7
	BPLB Highland	WY	--	SS, dol	18	388	275	9	3.0	70	30	81	11	4	0.50	3.0	30	6.4	3.2	--	3.2
	Madden	WY	35	dol	24	80	175	15	3.8	70	95	20	67	--	--	12	3.8	2.5	--	0.08	--
															Subtotal		177	93	55	3.1	52
Gulf Coast	Jackson Dome	MS	1,025	LS	16	90	185	13	2.8	70	95	90	5	--	0.00	5.0	24	16	11	1.8	8.9
Not Connected to a System	Escalante	UT	--	SS, LS	2.3	37	172	7	9.1	55	45	95	--	4	0.01	--	10	2.5	1.7	0.00	1.7
	Kevin Dome	MT	--	LS	3.6	261	67	9	5.3	75	95	88	--	12	--	--	14	10	1.1	--	1.1
	McCallum	CO	1.0	SS	5.5	15	100	20	3.5	70	90	92	--	--	0.11	--	2.8	1.8	1.5	0.87	0.6
	Gordon Creek	UT	--	LS	13	8	135	9	2.4	65	90	99	0	0	-	--	1.7	1.0	0.6	0.00	0.6
	Indian Creek	WV	0.1	SS	6.7	18	10	10	3.7	70	95	66	30	4	0.15	--	0.1	0.1	--	0.02	--
	Woodside	UT	--	SS	3.5	13	45	9	5.2	60	90	32	--	62	--	--	0.1	0.1	--	--	--
															Subtotal		29	15.4	4.9	0.90	4.1
																Total*	311	168	96.4	18.9	77.5

Conversion factor: 52.9 million metric tons CO_2 per Tcf, FVF= Formation Volume Factor (reservoir cf / thousand standard cf), GIIP=Gas Initially in Place, TRR=Technically Recoverable Resource,
Cumm Prdn = cumulative production through 2013, ERR= Economically Recoverable Resource, LS - limestone, SS = sandstone, dol = dolomite
* GIPP and TRR totals include four fields that are now inactive and not shown, field name (state, TCF GIIP): Estancia (NM, 0.9), Des Moines (NM, 1.0), Farnham (UT, 0.2) and Imperial (CA, 0.2)
Information Sources: (Adisoemerta, et al., 2004), (Ballentine, 2001), (Broadhead, 2009), (Lu, 2008), (Spangler, 2012), (Stilwell, 1989), (UGS, 2008), (Zimmerman, 1979).

The BPLB, in the Greater Green River basin of Wyoming, is the largest single discovered CO_2 resource in the U.S., with an estimated GIIP of 173 Tcf in aggregate, or 56 percent of the discovered resource base. The basinal portion of BPLB has an estimated remaining ERR of 43.2 Tcf. BPLB was originally developed for its methane content, but is experiencing significant increases in the use of its CO_2 in EOR.

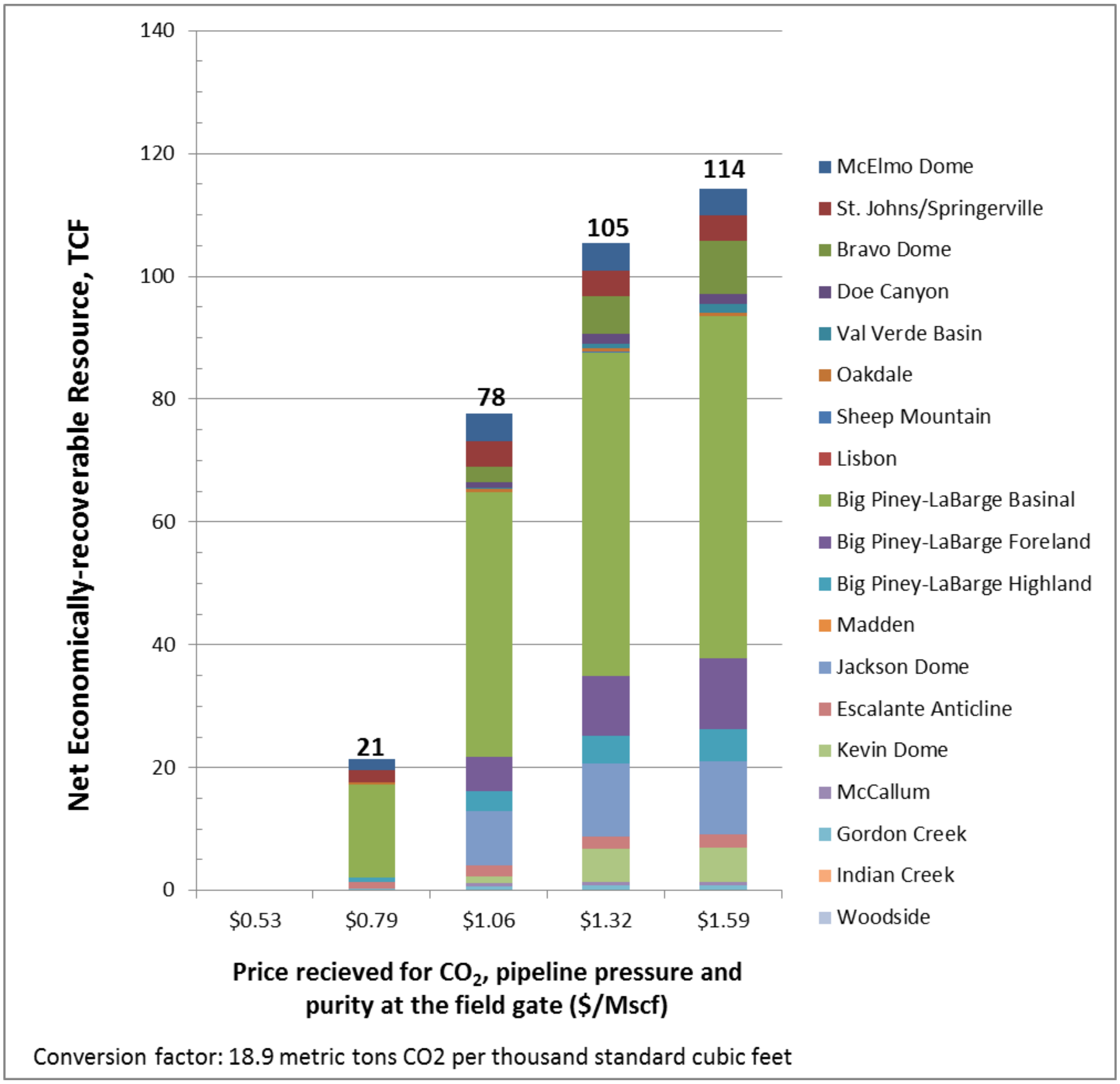
Other fields with 2 Tcf or more of gross ERR comprise McElmo Dome in Colorado and Utah (11.6 Tcf, currently producing and expanding), Jackson Dome in Mississippi (10.7 Tcf currently producing and expanding), BPLB foreland area in Wyoming (7.2 Tcf and currently producing), the Bravo Dome in New Mexico (5.4 Tcf and currently productive), St. Johns/Springerville in New Mexico and Arizona (4.3 Tcf under development), BPLB highland area in Wyoming (3.2 Tcf), and the Val Verde Basin (1.6 Tcf currently producing and expanding). McElmo Dome field, a workhorse for CO_2 supply, producing about 1.1 Bcf/d, is estimated in CREAM to be past peak production and is modeled as having about 4.4 Tcf of ERR remaining, although available data in the public domain lead to uncertain estimates. Fields in the Val Verde basin in Texas, located close to EOR developments, have been exploited for CO_2. CREAM is able to discriminate the seven fields located in the Val Verde basin only by CO_2 content, and compute an aggregate ERR estimate of about 0.1 Tcf in aggregate left to produce in ERR.

Other noteworthy fields include, Escalante Anticline in Utah (1.7 Tcf undeveloped and largely inaccessible), Kevin Dome in Montana (1.1 Tcf producing), and the Doe Canyon field (1.1 TCF under development), located near McElmo field. CREAM estimates are higher than Kinder-Morgan CO_2's indication adding 750 Bcf of reserves. (Bradley, 2011) The McCallum field in Colorado is currently producing and has about 627 Bcf of ERR. The Gordon Creek field in Utah is in development and is estimated to contain about 604 Bcf of ERR.

Sheep Mountain field, a productive field since its discovery in the 1970s, is modeled as being nearly depleted. The Madden field, which has been developed for its methane but contains 20 percent CO_2, has about 2.5 Tcf of CO_2 TRR (the fact that CREAM is showing no CO_2 ERR is a reflection of the fact that it would not be economically viable to develop the field for its CO_2 resources alone). At Madden, the Lost Cabin natural gas processing facility is being expanded to capture the CO_2 (up to 60 MMcfd) for use in EOR in Wyoming and Montana. (Condon, 2011) The Des Moines field, in New Mexico, is proximal to Bravo Dome and has about 600 Bcf of TRR. The remaining eight fields examined are small, on the order of less than 500 Bcf each (and about 2 Tcf in aggregate) and are less likely to contribute to CO_2 supply.

The spreadsheet tool, CREAM, was exercised to assess the sensitivity of the ERR estimates to the assumed field gate price for CO_2. Exhibit 4-2 shows the results in terms of net ERR, that is the gross ERR minus cumulative production. From the reference value of \$1.06/Mscf (20 \$/mtCO_2), a 25% drop in CO_2 price causes a 73% drop in net ERR; a 25% increase in CO_2 price causes a 35% increase in net ERR. None of the fields are economic at \$0.53/Mscf. Bravo, Doe Canyon, Val Verde and Kevin Dome all realize significant increase in net ERR going from \$1.06 /Mscf to \$1.32/Mscf. The reason for this is that tiers within the reservoir become economic with higher revenue.

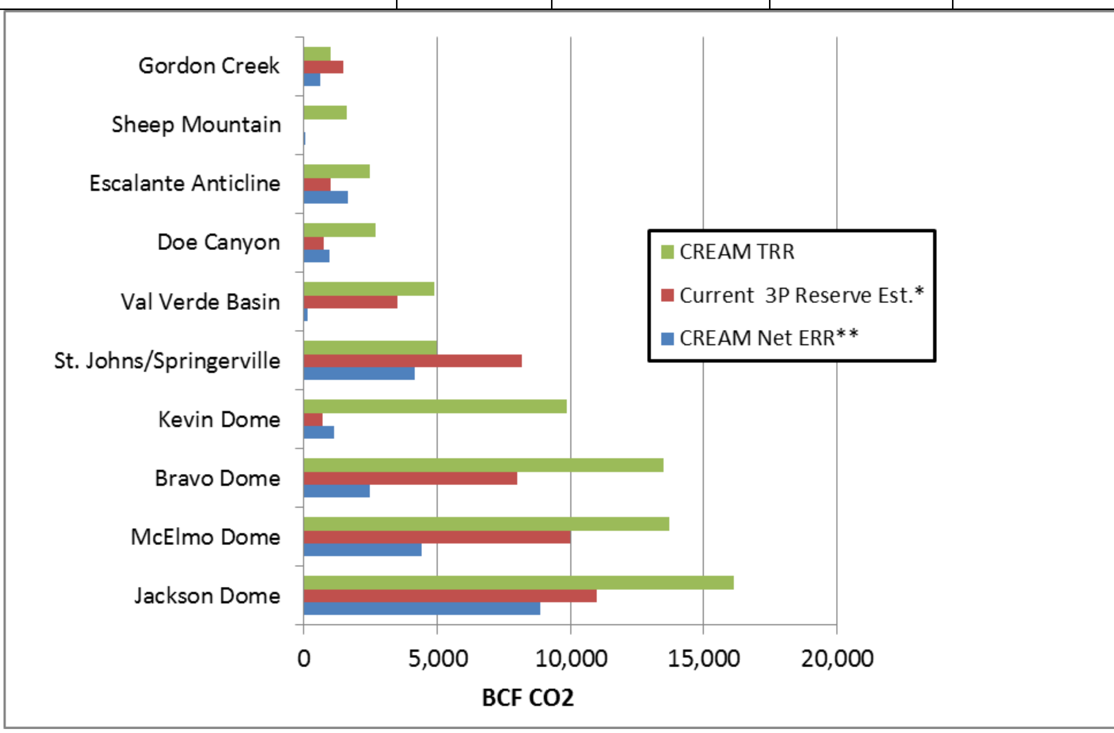
Exhibit 4-2 Sensitivity of net ERR to CO_2 price



Comparison of CREAM results has been made with owner/operator 3P estimates as compiled in a note by DiPietro *et al.* (DiPietro, 2012) as shown in Exhibit 4-3. Big Piney Labarge is included in the table but not in the graphical element for scale. All of the fields listed in the note were analyzed with CREAM. Overall, the company estimates show a somewhat smaller volume of CO_2 reserves (approximately 147 Tcf) compared to CREAM TRR (161 Tcf for the same fields). Some of this variation can be explained by inconsistency of the application of the term “reserves” in the literature, or access to data not publicly available to CREAM. Over two thirds of the company 3P reserves (102 Tcf) are allocated to BPLB compared to CREAM (90 Tcf of TRR for the whole of BPLB).

Exhibit 4-3 CO_2 results comparison

Structure or Field	State	Current 3P Reserve Est.* (Bcf)	CREAM TRR (Bcf)	CREAM Net ERR** (Bcf)
Big Piney-LaBarge (All)	WY	102,400	90,213	51,989
Jackson Dome	MS	11,000	16,123	8,878
St. Johns/Springerville	NM, AZ	8,200	4,994	4,155
Bravo Dome	NM	8,000	13,518	2,468
McElmo Dome	CO, UT	10,000	13,693	4,439
Escalante Anticline	UT	1,000	2,495	1,652
Kevin Dome	MT	700	9,850	1,124
Doe Canyon	CO	750	2,675	972
Gordon Creek	UT	1,500	1,006	604
Val Verde Basin	TX	3,500	4,895	131
Sheep Mountain	CO	Depleted	1,595	55
Total		**147,050**	**161,057**	**76,467**



* (DiPietro, 2012) ** based on a CO_2 price of $20/tonne at the field gate

In Bravo Dome, CREAM is showing less than twice as much TRR as in 3P estimates but a significantly lower ERR volume. At Jackson Dome and Bravo dome, CREAM estimates bracket 3P estimates. At St. Johns/Springerville CREAM estimates are about half of 3P estimates. At Escalante Anticline, CREAM is depicting almost two and a half times as much TRR (2.5 Tcf) and over one a half times as much ERR (1.6 Tcf) as company estimates show (1 Tcf). Other fields of note are Doe Canyon, where CREAM ERR is consistent with 3P estimates (and announced company plans for development (Bradley, 2011)) and Sheep Mountain, which is considered to be depleted and where CREAM confirms negligible remaining ERR.

Overall, of the TRR assessed in this study, about 58 percent may yet be economically recoverable. The Big Piney-LaBarge field in Wyoming contains an estimated remaining ERR of 52 Tcf, 67 percent of the total for the United States. The remaining ERR in reservoirs that feed into the Permian Basin and Gulf Coast is on the order of 10-20 years of supply. The technically recoverable resource (TRR) in the Permian Basin and Gulf Coast is on the order of 30 years of supply. The ERR at LaBarge contains an estimated 260 Bcf of helium, while the ERR at St Johns/Springerville may contain 25 Bcf of helium.

4.2 Uncertainty

There are other areas of uncertainty in the estimates for GIIP, TRR and ERR. For example, we were not able to find unique maps for Bravo or Jackson Dome. The cost and performance of helium capture systems and other gas processing operations are held as proprietary. We do not have production well models or systems analyses of gas processing systems to predict CO_2 compressor inlet pressure at each field. The TRR recovery factors (%GIIP recoverable) are based on literature research and the expertise of the authors rather than measurements of reservoir permeability. Well spacing is generically applied. NETL is undertaking efforts to address these areas of uncertainty and others and plans to publish an updated version of its working paper.

Another source of uncertainty in the resource estimate is the potential for discovery of new CO_2 field(s). Accordingly, NETL is undertaking a parallel effort to identify and assess leads for undiscovered CO_2 resources in the United States. That study looks more closely at the geology and tectonics of the discovered CO_2 reservoirs and the sequence of trap formation and CO_2 emplacement. The study then explores five areas for possible undiscovered leads within the geologic trends where the discovered reservoirs are found. A companion NETL document contains the analysis of undiscovered CO_2 resources.

5 References Cited

Adisoemerta, P.S. and S.M. Frailey, and A.S., Lawal. 2004. *Measured Z Factor of CO2--Dry Gas/Wet Gas/Gas Condensate for CO2 Storage in Depleted Reservoirs, Society of Petroleum Engineers Paper 89466.* s.l. : Society of Petroleum Engineers, 2004.

Avary, K. L. 1996. Play Sts: The Lower Silurian Tuscarora Sandstone Fractured Anticlinal Play. *The Atlas of Major Appalachian Gas Plays: West Virginia Geological and Economic Survey.* 1996, Vols. V-25, pp. 151-155.

Ballentine, C., M. Schoell, D. Coleman, and B. Calm. 2001. 300-Myr-old magmatic CO2 in natural gas reservoirs on the west Texas Permian basin. *Nature.* 2001, Vol. 409, p. 327.

BGR. 2003. What is CCS? *BGR.* [Online] 2003. [Cited: February 11, 2013.] http://www.bgr.bund.de/EN/Themen/CO2Speicherung/FAQ/faq_node_en.html#doc1559834bodyText1.

BLM. 2011. EPCA Phase III Inventory. [Online] 2011. [Cited: February 11, 2013.] http://www.blm.gov/wo/st/en/prog/energy/oil_and_gas/EPCA_III.html.

—. 2013. Federal Helium Program Frequently Asked Questions, What are the BLM's prices for crude helium? What will the helium prices be next year? [Online] 2013. [Cited: May 11, 2013.] http://www.blm.gov/nm/st/en/prog/energy/helium/federal_helium_program/federal_helium_program.html.

—. 2002. *Mineral Potential Report: Bureau of Land Management, Price, Utah Field Office.* 2002.

Boyce, Richard G. 2009. Unlocking Multiple plays in a Developing Resource. *dB, LLC Petroleum Advisors.* [Online] Mar 27, 2009. [Cited: Feb 13, 2014.] http://www.slideshare.net/dbseismo/west-texas-overthrust-play.

Bradley, T. and J. Wuerth. 2013. CO2 Kinder Morgan investor presentation. [Online] 2013. [Cited: February 11, 2013.] http://www.-kindermorgan.com/investor/presentations/013013_CO2.pdf .

Bradley, T. 2011. CO2 Kinder Morgan investor presentation. [Online] 2011. [Cited: February 11, 2013.] http://www.kindermorgan.com-/investor/presentations/presentations.cfm?year=2011.

Broadhead, R. F., M. Mansell and G. Jones. 2009. *Carbon Dioxide in New Mexico: Geologic Distribution of Natural Occurrences.* s.l. : New Mexico Bureau of Geology and Mineral Resources, Open File Report No. 514, 2009.

Cassidy, M. 2005. *Occurrence and Origin of Free Carbon Dioxide Gas Deposits in the Earth's Continental Crust.* s.l. : PhD. Dissertation, Dept. of Geosciences, University of Houston, 2005.

Chidsey, T., C., M. Laine, J. Vrona, and D. Strickland. 2007. *Covenant Oil Field, Central Utah Thrust Belt: Possible Harbinger of Future Discoveries, American Association of Petroleum Geologists Search and Discovery Article #10130.* s.l. : American Association of Petroleum Geologists, 2007.

Cline, C., A. Hoksberg, R. Abry, and A. Janssen. 2012. Biological Process For H2s Removal From Gas Streams. The Shell-Paques/Thiopaq™ Gas Desulfurization Process. [Online] 2012. [Cited: February 11, 2013.] http://www.environmental-expert.com/Files/587/articles/5529/paques6.pdf.

Condon, C. and M. Parker. 2011. Shute Creek Treating Facility Project Updates. [Online] The Wyoming Enhanced Oil Recovery Institute 5th Annual Wyoming CO2 Conference. July 13, 2011. [Cited: February 11, 2013.] http://www.uwyo.edu/eori/_files/co2conference11/clay%20%20exxonmobil%202011%20eori%20presentation%20-%20final.pdf.

ConocoPhillips. undated. Lost Cabin Gas Plant CO2. [Online] undated. [Cited: February 11, 2013.] http://www.uwyo.edu/eori-/_files/co2conference07/brent_lohnes_conocophillips_eori.pdf.

Denbury. 2012. Analyst Day Presentation. [Online] November 2012. [Cited: February 11, 2013.] http://www.denbury.com/files/2012-11%20Analyst%20Meeting%20FINAL_v001_q03n07.pdf.

—. July 2013. *Rocky Mountain Activity Update.* July 2013. pp. 16-25.

DiPietro, P., P. Balash, and M. Wallace. 2012. *A Note on Sources of CO2 Supply for Enhanced-Oil-Recovery Operations.* s.l. : Society of Petroleum Engineers Economics & Management, 2012.

EIA. 2013. AEO2013 Early Release Overview. [Online] 2013. [Cited: February 11, 2013.] http://www.eia.gov/forecasts/aeo/er/index.cfm.

—. 2012. Natural Gas, Data, Number of Producing Gas Wells. [Online] 2012. [Cited: February 11, 2013.] http://www.eia.gov/dnav/ng/ng_prod_wells_s1_a.htm.

—. 2013. *Status and outlook for shale gas and tight oil development in the U.S.* for Platts – North American Crude Marketing Conference. Houston, TX : U.S. Energy Information Administration, 2013.

EPA. 2008. Methane to Markets, Natural Gas Dehydrator Optimization, IAPG & US EPA Technology Transfer Workshop. [Online] 2008. [Cited: February 11, 2013.] http://www.epa.gov/gasstar/documents/workshops/buenosaires-2008/dehydrator_optimization.pdf.

ETSAP. 2010. Conventional Oil and Gas Technologies. [Online] 2010. [Cited: November 2, 2013.] http://www.iea-etsap.org/web/P01-Conv-Oil&Gas-GS-gct-AD.pdf.

Feytis, A. 2012. Sulfur Prices CFR Tampa drop 15% from 2011 Year End. [Online] 2012. http://www.indmin.com/Article/2995706/Sulphur-prices-CFR-Tampa-drop-15-from-2011-year-end.html.

Fox, C. 2013. Personal communication. 2013.

Gilfillan, S., C. Ballentine, G. Holland, D. Blagburn, B. Sherwood Lollar, S. Stevens, M. Schoell, and M. Cassidy. 2008. The noble gas geochemistry of natural CO2 gas reservoirs from the Colorado Plateau and Rocky Mountain provinces. *Geochimica et Cosmochimica Acta.* 2008, Vol. 72, 4, pp. 1174-1198.

Gilluly, J. 1929. *U.S. Geological Survey. Bulletin 806-C.* 1929.

Hamak, J. E., and B. D. Gage. 1992. *Analyses of natural gases, 1991: U.S. Bureau of Mines Information Circular IC 9318.* 1992. p. 97.

Hamak, J. E., and S. Sigler. 1991. *Analyses of natural gases, 1986-1990: U.S. Bureau of Mines Information Circular IC 9301.* 1991. p. 315.

Hare, M., H. Perlich, R. Robinson, M. Shah, and F. Zimmerman. 1978. *Sources and Delivery of Carbon Dioxide for Enhanced Oil Recovery.* s.l. : US. Department of Energy, Contract No. EX-76-C-01-2515, 1978.

Hester, R. and R. Holland. 1959. *Structure of the Puckett Field, Pecos County, Texas, 1959 Val Verde Field Trip Guidebook.* 1959.

Holz, M., P. Nance, and R. Finley. 1999. *Reduction on Greenhouse Gas Emissions through Underground CO2 Sequestration in Texas Oil and Gas Reservoirs.* s.l. : Bureau of Economic Geology, 1999.

IEA. 2009. *Greenhouse Gas Program—Development of Storage Coefficients for Carbon Dioxide Storage in Deep Saline Formations, Technical Study Report No. 2009/13, Table 2.* 2009.

INGAA. 2010. *CCS Transport, Barriers to Widespread Deployment.* 2010.

—. 2011. North American Natural Gas Midstream Infrastructure Through 2035: A Secure Energy Future. [Online] 2011. [Cited: February 11, 2013.] http://www.ingaa-.org/File.aspx?id=14911.

Jenden, P.D., D.J. Drazan, and I.R. Kaplan. 1993. Mixing of thermogenic natural gases in northern Appalachian basin. 1993, Vol. 77, pp. 980-998.

Khayyal, T. July 2013. *LaBarge/Shute Creek Facility Update.* s.l. : The Wyoming Enhanced Oil Recovery Institute, 7th Annual Wyoming CO2 Conference, July 2013. pp. 3-9.

Kinder Morgan CO2. 2013. McElmo Dome. [Online] 2013. [Cited: February 11, 2013.] http://www.kindermorgan-.com/business/co2/supply_mcelmo.cfm.

Lake, J. Nad S. Whittaker. 2006. Occurrences of CO2 within southwest Saskatchewan: Natural analogues to the Weyburn CO2 injection site. *Summary of Investigations.* Saskatchewan Geological Survey, Misc. Rep. 2006-4.1, 2006, Vol. 1, Paper A-5, p. 14.

Lu, M., and L. D. Connell. 2008. Non-isothermal flow of carbon dioxide in injection wells during geological storage, Figure 1. *International Journal of Greenhouse Gas Control 2.* 2008. pp. 248-258.

MGS. 1985. Montana Oil & Gas Fields, Figure 2. s.l. : Montana Geological Society Symposium, 1985.

Mitaritan, M. 2009. Economic N2 Removal, Hydrocarbon Engineering Magazine, 2004 (updated 2009). [Online] 2009. [Cited: February 11, 2013.] http://www.moleculargate.com/nitrogen-rejection-N2-removal/Economic-N2-Removal-Hydrocarbon-Engineering.pdf.

Moore, J. and M. Adams, R. Allis, S. Lutz, and S. Rauzi. Arizona and New Mexico, Second Annual Conference on Carbon Sequestration. 2003. CO2 Mobility in Natural Reservoirs Beneath the Colorado Plateau and Southern Rocky Mountains: An Example from the Springerville-St. Johns Field. [Online] Arizona and New Mexico, Second Annual Conference on Carbon Sequestration. 2003. [Cited: February 11, 2013.] http://geology.utah.gov/emp/co2sequest/pdf/mobility.pdf.

Muffler, P., and D. White. 1968. Origin of CO2 in the Salton Sea Geothermal System, Southeastern California, U.S.A. *XXIII International Geological Congress.* 1968, Vol. 17, pp. 185-194.

Murrell, Glen, and Phil DiPietro. 2013. North American CO2 Supply and Developments. *University of Wyoming.* [Online] Dec 11-13, 2013. [Cited: Feb 13, 2013.] http://www.co2conference.net/wp-content/uploads/2013/12/2-Dipietro-CO2-Supply-2013_v7.pdf.

National Academies. 2010. *"4 Helium Sourcing and Reserves." Selling the Nation's Helium Reserve.* Washington D.C. : The National Academies Press, 2010.

NETL. undated. Natural CO2 Reservoirs on the Colorado Plateau and Southern Rocky Mountains: Candidates for CO2 Sequestration. [Online] undated. [Cited: February 11, 2013.] http://www.netl.doe.gov/publications/proceedings/01/carbon_seq/6a2.pdf.

SMU. undated. Enhanced Geothermal Systems Potential in Google Earth. [Online] undated. [Cited: February 11, 2013.] http://www.google.org/egs/.

Spangler, L. Bowen, D., Talbot, J. 2012. *Montana Characterization Study - Comprehensive Report Deliverable Gd30 (Task 15).* National Energy Technology Laboratory Infrastructure Meeting : Big Sky Carbon Sequestration Partnership, 2012.

Stevens, S.H., J. M. Pearce, and A. A. J. Rigg. May 15-17, 2001. *Natural Analogs for Geologic Storage of CO2: An Integrated Global Research Program.* s.l. : U.S. Department of Energy, National Energy Technology Laboratory, May 15-17, 2001.

Stilwell, D. 1989. *CO2 Resources of the Moxa Arch and the Madison Reservoir.* s.l. : Wyoming Geological Association, Fourth Field Conference Guidebook, 1989.

Summers, M. 2013, in publication. *Cost of Capturing CO2 from Industrial Sources Final Draft – Revision 1.* s.l. : The National Technology Laboratory, 2013, in publication.

UGS. 2008. *The Mississippian Leadville Limestone Exploration Play, Utah and Colorado – Exploration Techniques and Studies for Independents, Oil & Natural Gas Technology Semi-Annual Technical Progress Report.* s.l. : National Energy Technology Laboratory, 2008.

USGS. 1959. *Geology of the Huerfano Park area, Huerfano and Custer Counties, Colorado.* s.l. : USGS Bulletin 1071-D, 1959. pp. 87-119.

—. 2007. Petroleum systems and assessment of undiscovered oil and gas in the Raton Basin–Sierra Grande Uplift Province, Colorado and New Mexico. *Petroleum systems and assessment of undiscovered oil and gas in the Raton Basin–Sierra Grande Uplift Province, Colorado and New Mexico-USGS Province 41.* s.l. : USGS Digital Data Series DDS-69-N, 2007, 2, p. 124.

—. 2012. *Variability of Distributions of Well-Scale Estimated Ultimate Recovery for Continuous (Unconventional) Oil and Gas Resources in the United States, Open-file report 2012-1118.* 2012.

Wandrey, C. and C. Barker. undated. Park Basins Province (038) with a section on Upper Cretaceous Niobrara Fractured Calcareous Shale Oil by R. Pollastro. *U.S. Geological Survey.* [Online] undated. [Cited: February 11, 2013.] http://certmapper.cr.usgs.gov/data/noga95/prov38/text/prov38.pdf.

Washington Post. 2012. "Congress turns its attention to... America’s helium crisis". [Online] 2012. [Cited: May 11, 2013.] http://www.washingtonpost.com/blogs/wonkblog/post/congress-turns-its-attention-to-americas-helium-crisis/2012/05/12/gIQA4fIbKU_blog.html.

Wiseman, Paul. 2012. Kinder Morgan CO2 readies Doe Canyon expansion, adds St. Johns field. *Midland Reporter-Telegram.* [Online] Feb 24, 2012. [Cited: Jan 23, 2014.] http://www.mrt.com/business/oil/top_stories/article_3143d85f-8ad8-5997-9702-4373aea5a3d9.html?mode=print.

Worrall, J. 2003. *Preliminary geology of the Oakdale field, NW Raton Basin, Huerfano County, Colorado: AAPG Search and Discovery Article 90023-2002.* Ruidoso, New Mexico : AAPG Southwest Section Meeting, 2003. pp. 56-69.

Zimmerman. 1979. *Naturally Occurring Carbon Dioxide Sources in the United States -- A Geologic Appraisal And Economic Sensitivity Study of Drilling and Producing Carbon Dioxide for Use in Enhanced Oil Recovery.* s.l. : Gulf Universities Research Consortium Report No. 165, Final Draft, 1979.

Appendix 1 Field Location Maps

Exhibit A1-1 Big Piney-LaBarge CO_2 field areas

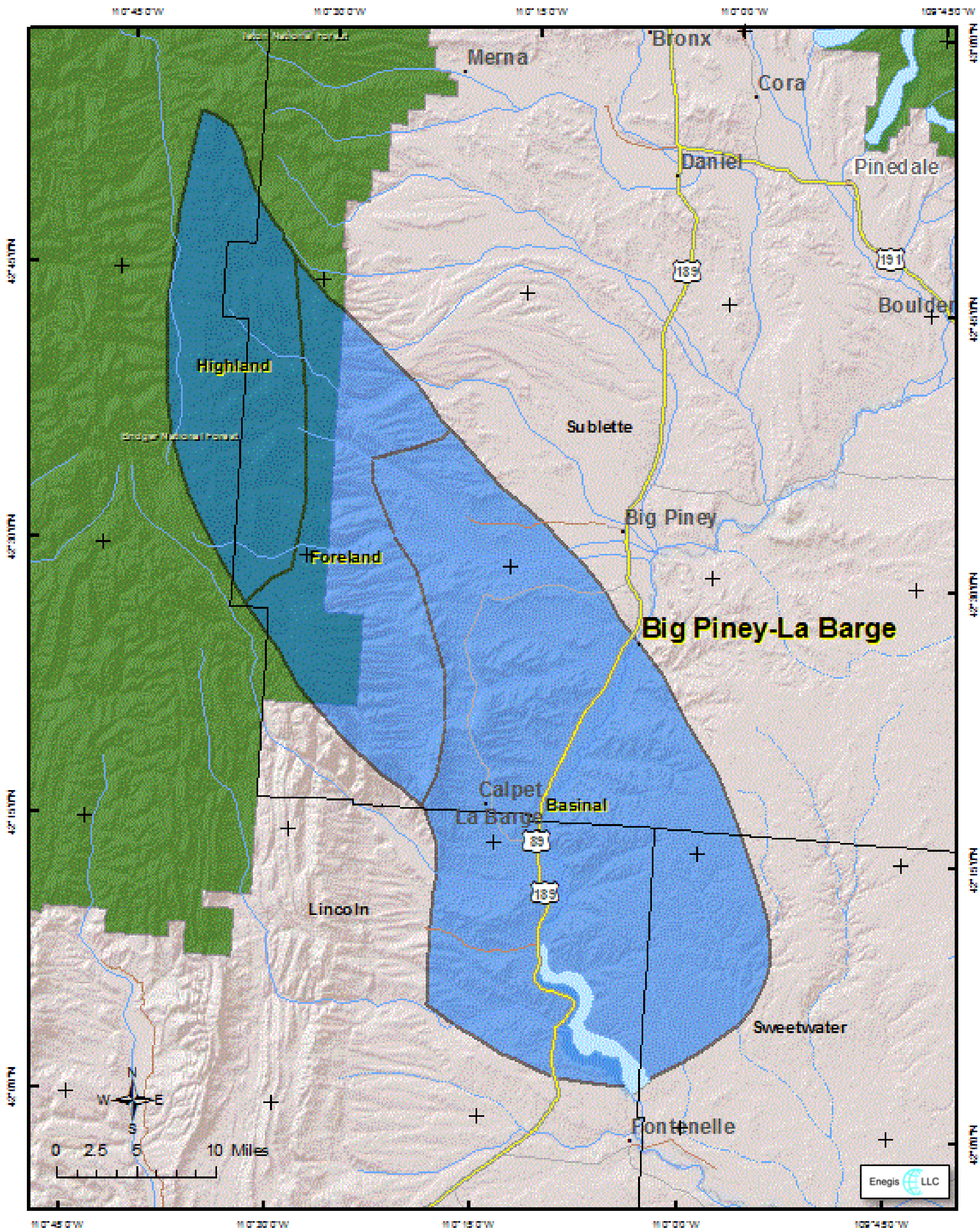


Exhibit A1-2 Bravo Dome CO_2 field

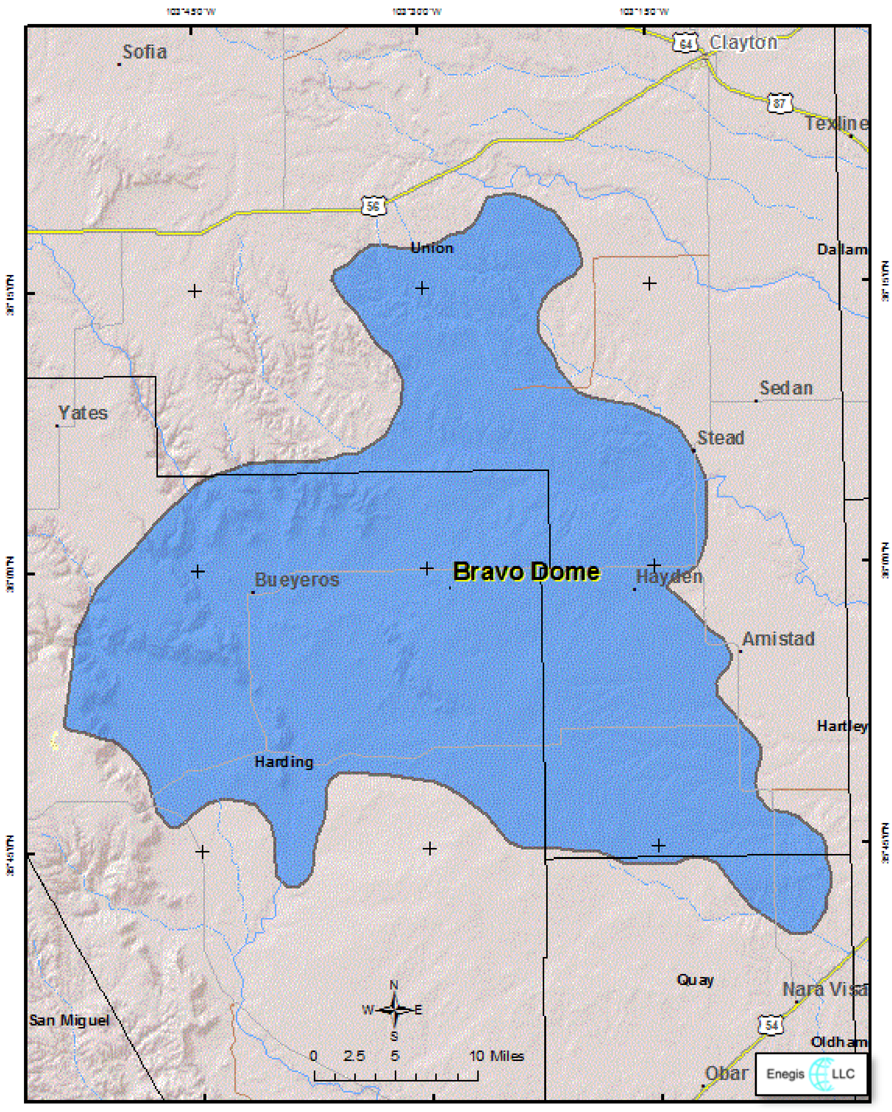


Exhibit A1-3 Des Moines CO_2 field

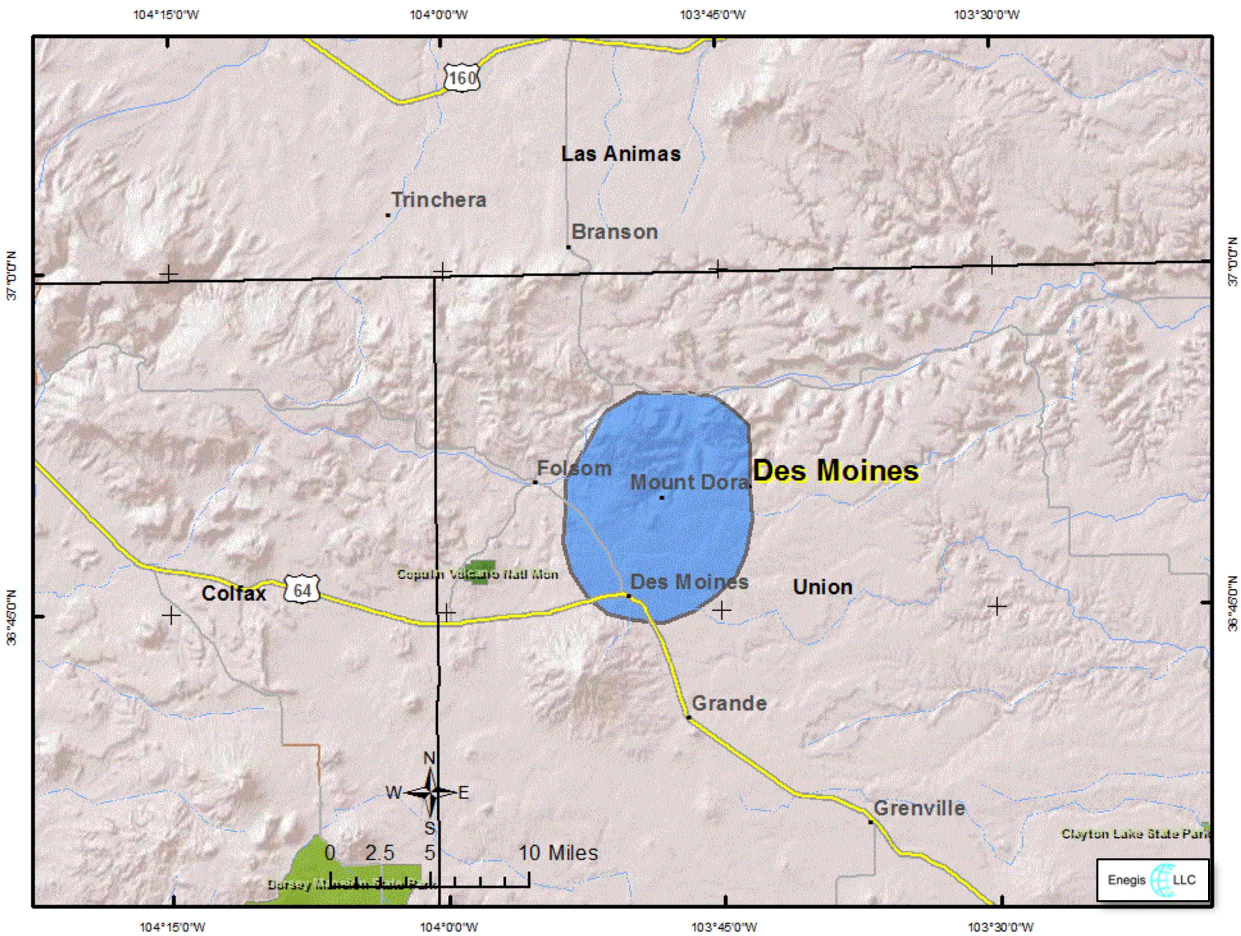


Exhibit A1-4 Doe Canyon CO_2 field

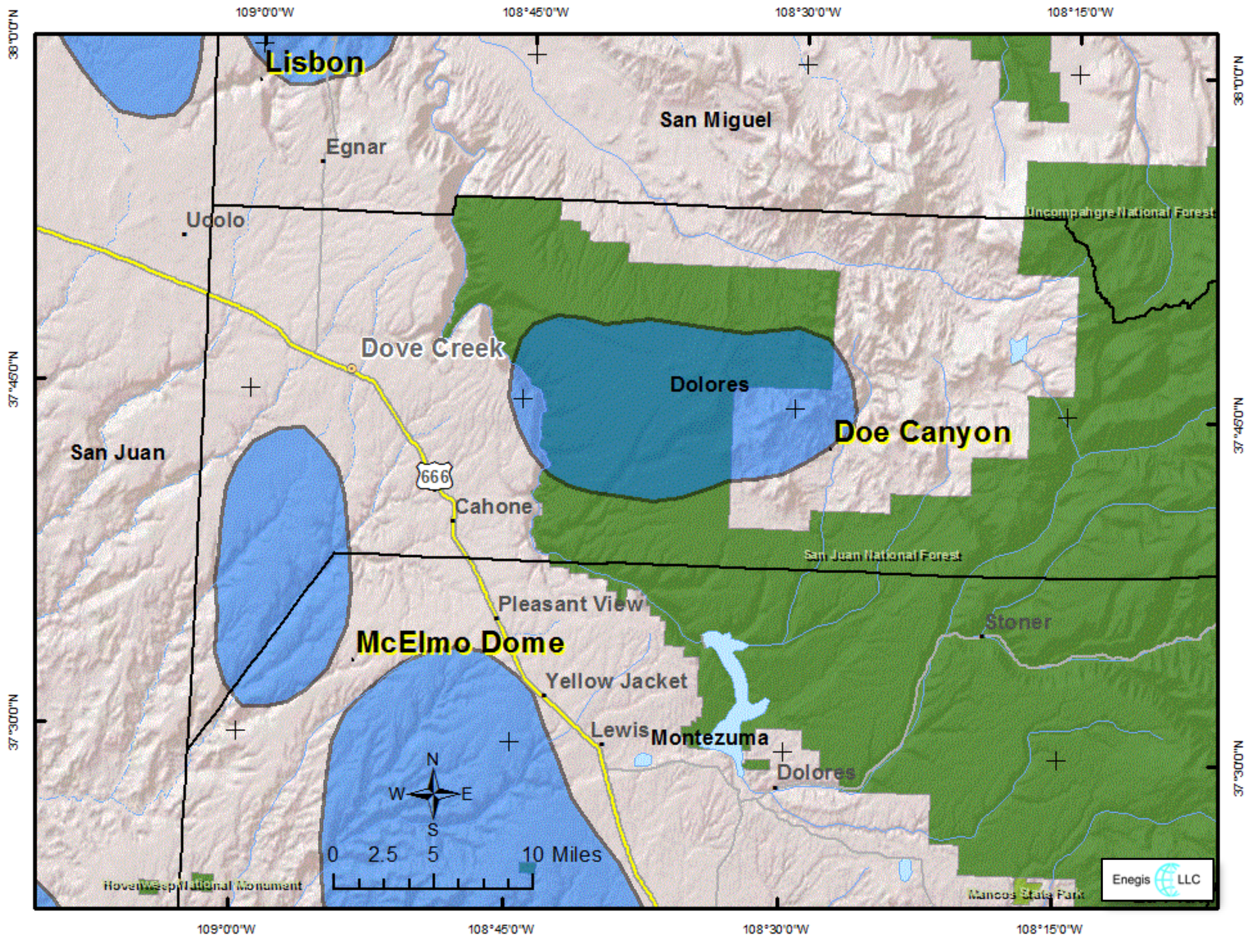


Exhibit A1-5 Escalante Anticline CO_2 field

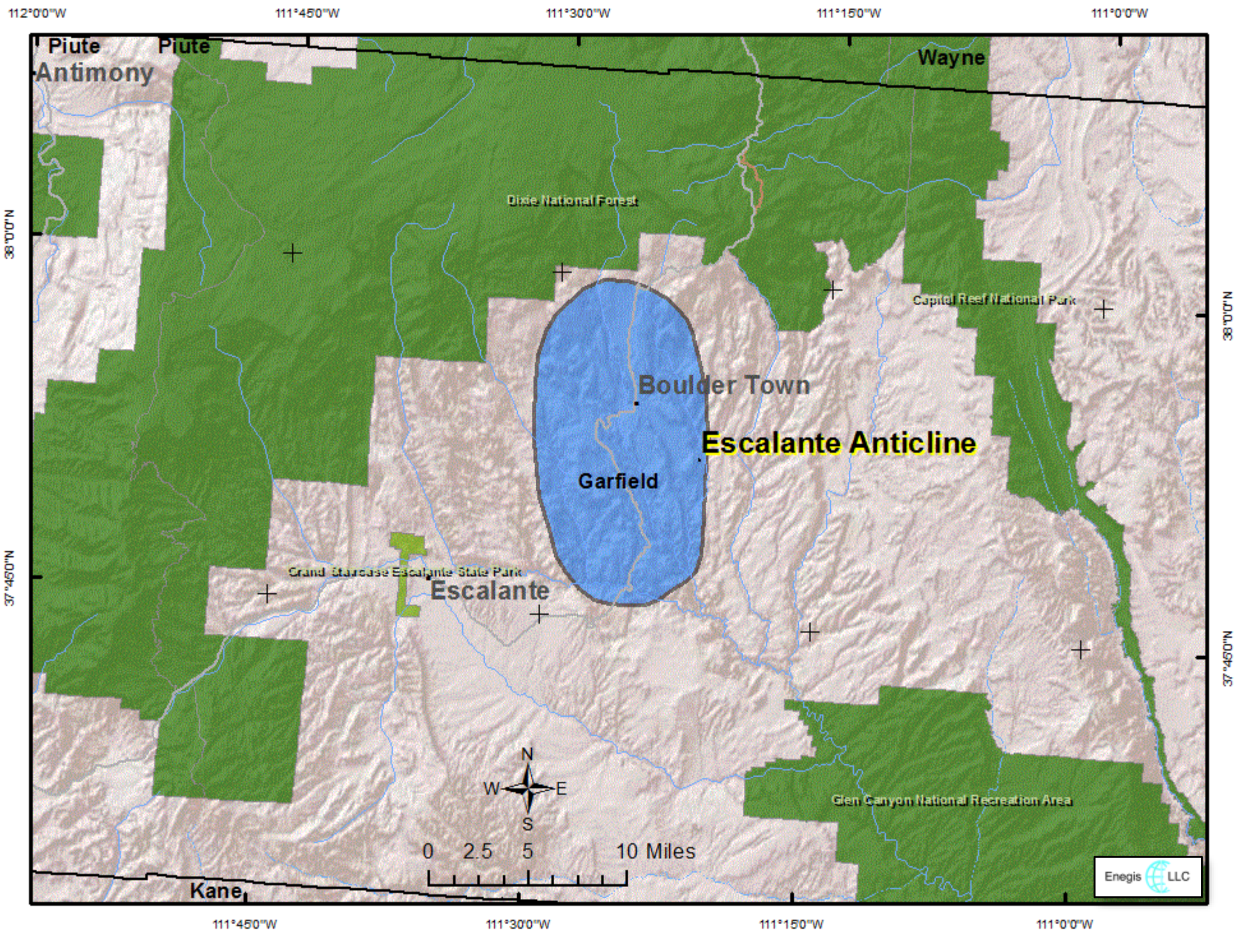


Exhibit A1-6 Estancia CO_2 field

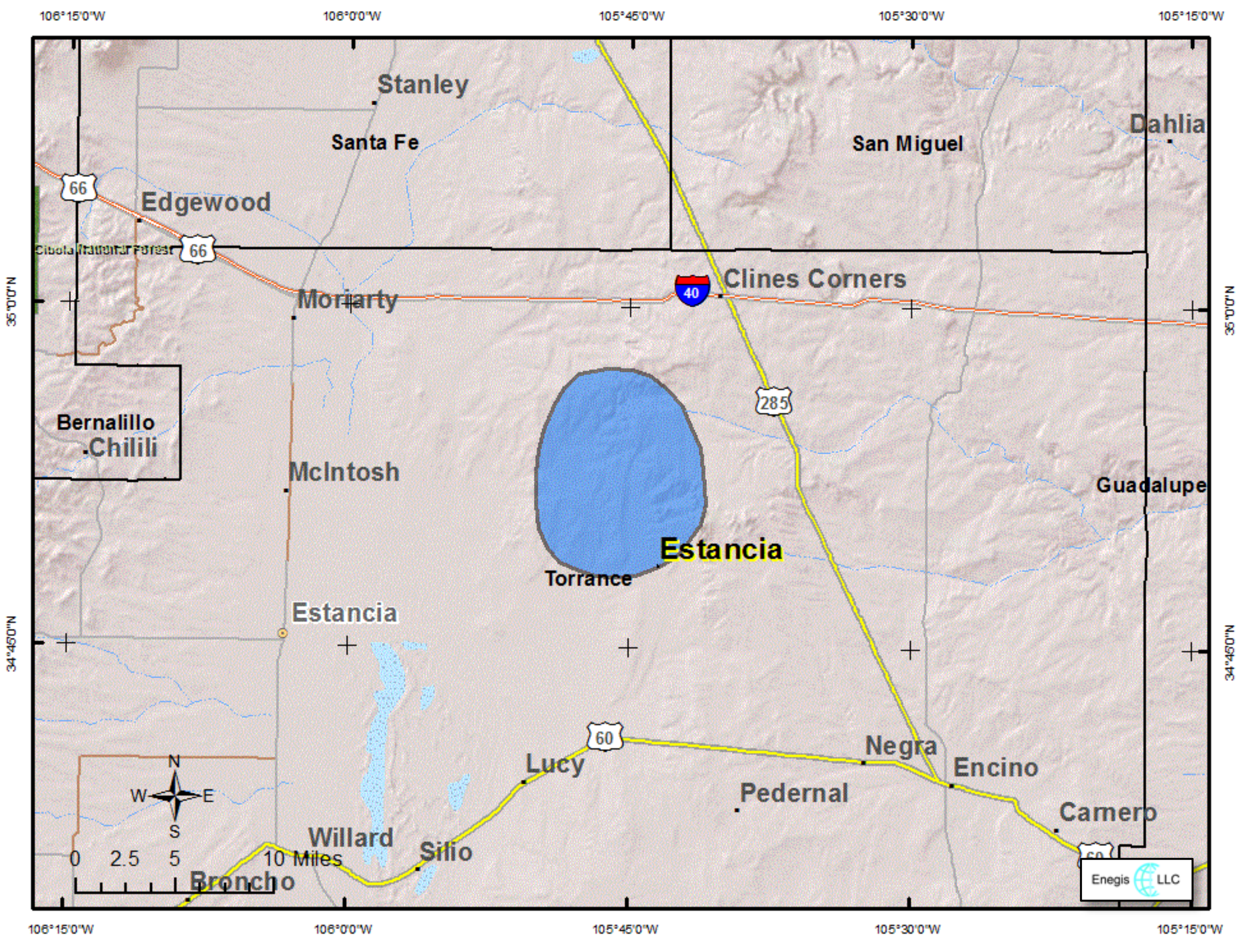


Exhibit A1-7 Gordon Creek, Farnham Dome and Woodside CO_2 fields

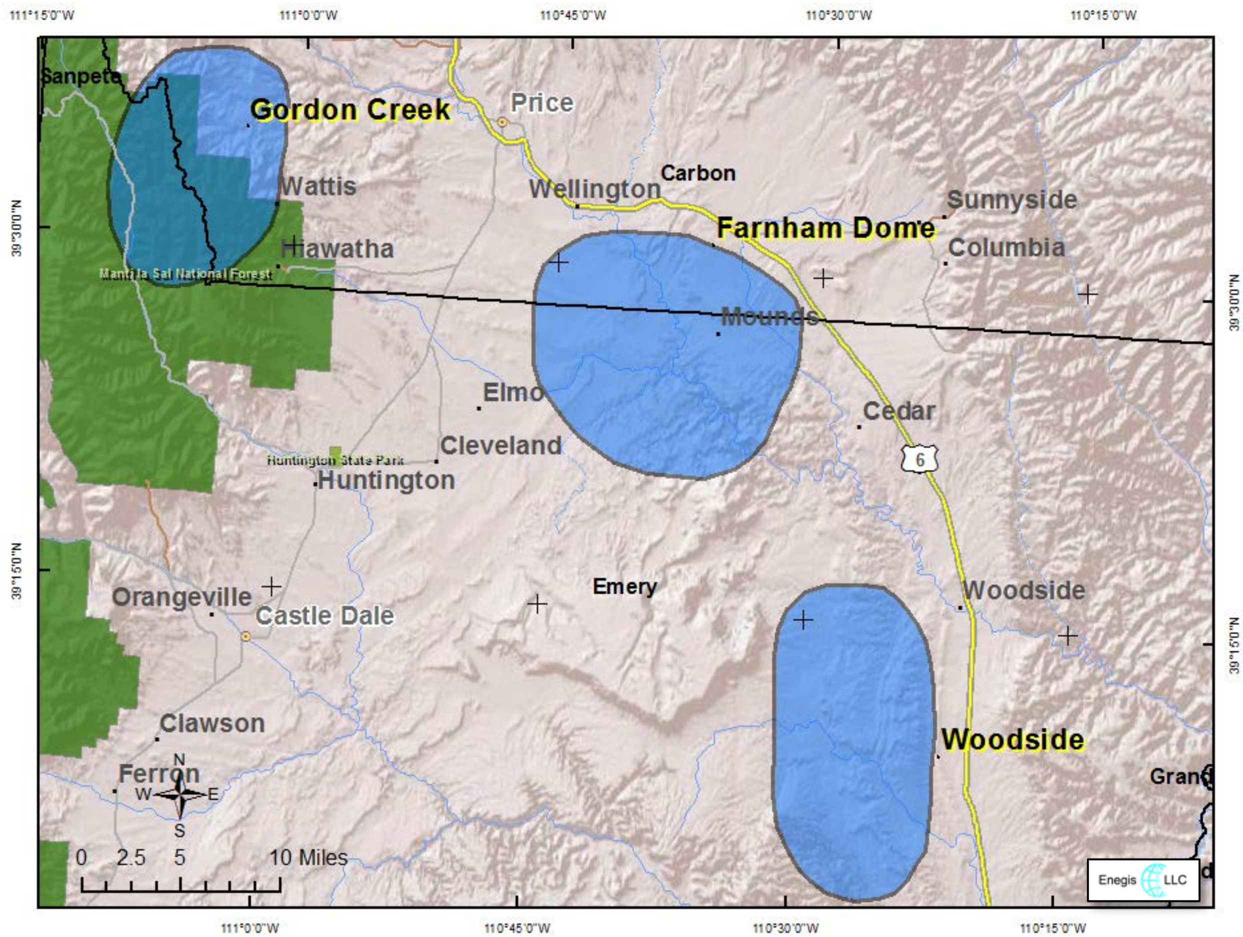


Exhibit A1-8 Imperial CO_2 field

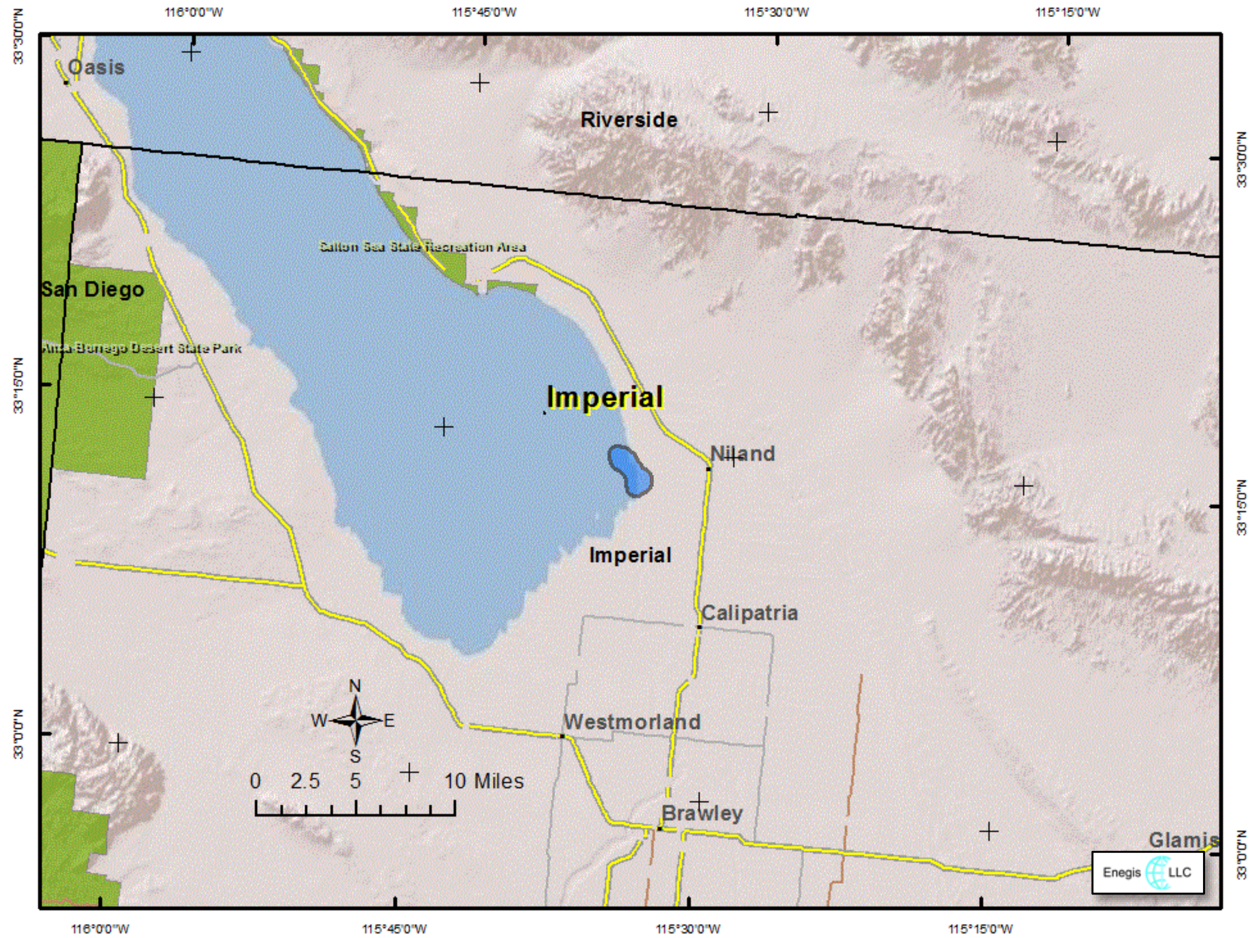


Exhibit A1-9 Indian Creek CO_2 field

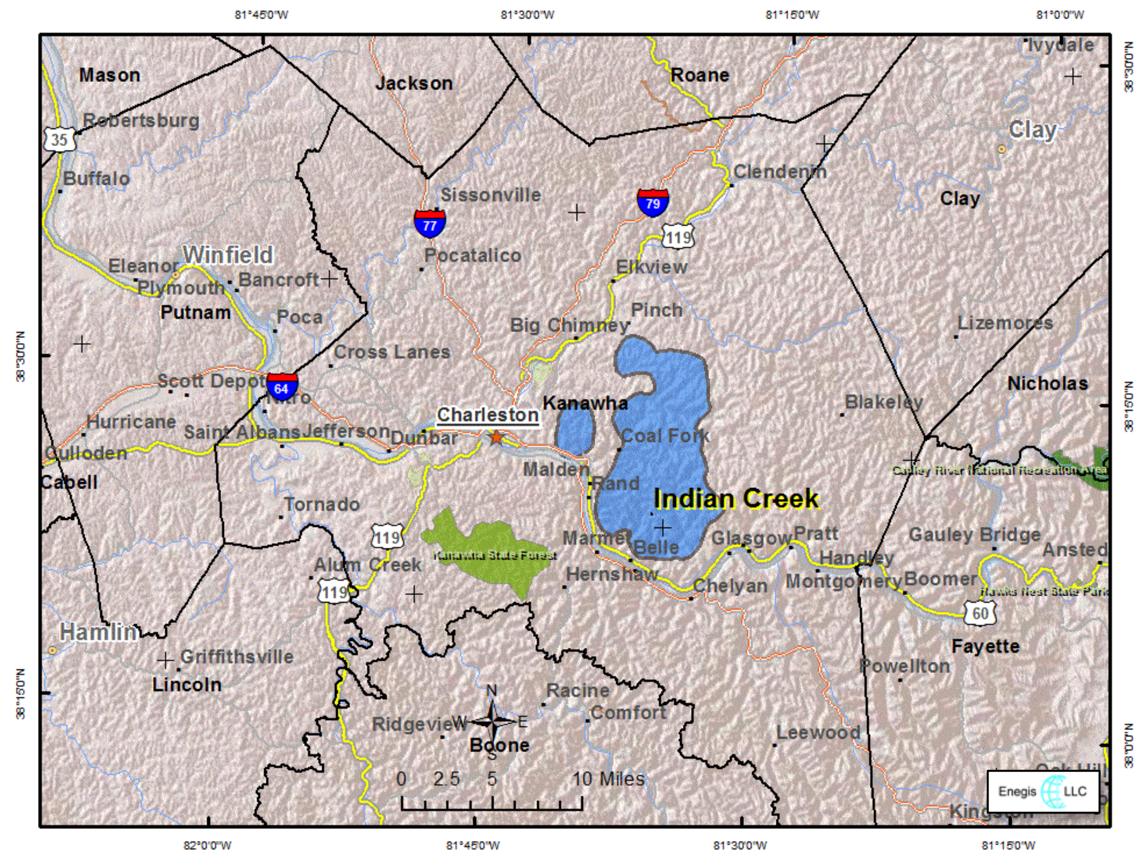


Exhibit A1-10 Jackson Dome CO_2 field

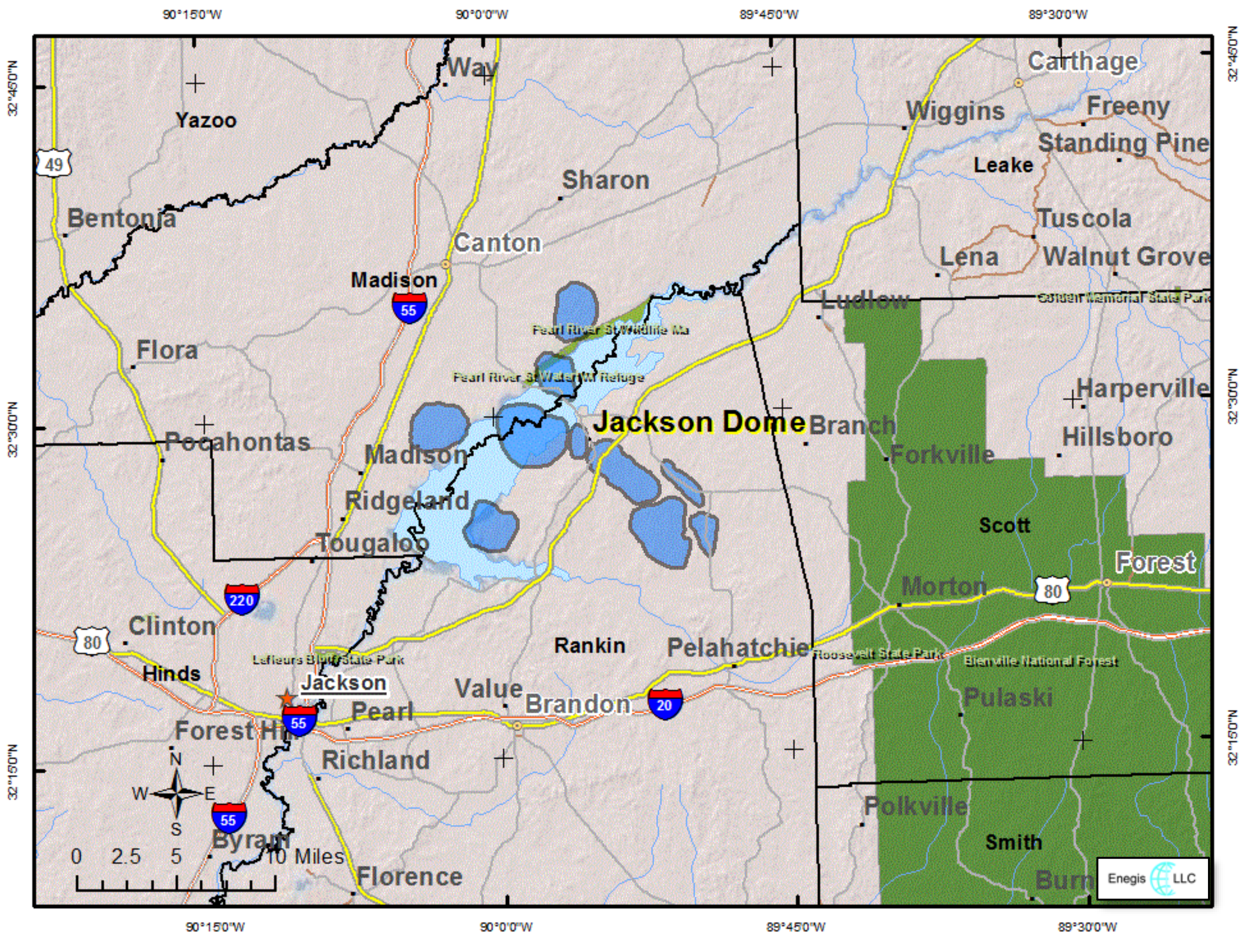


Exhibit A1-11 Kevin Dome CO_2 field

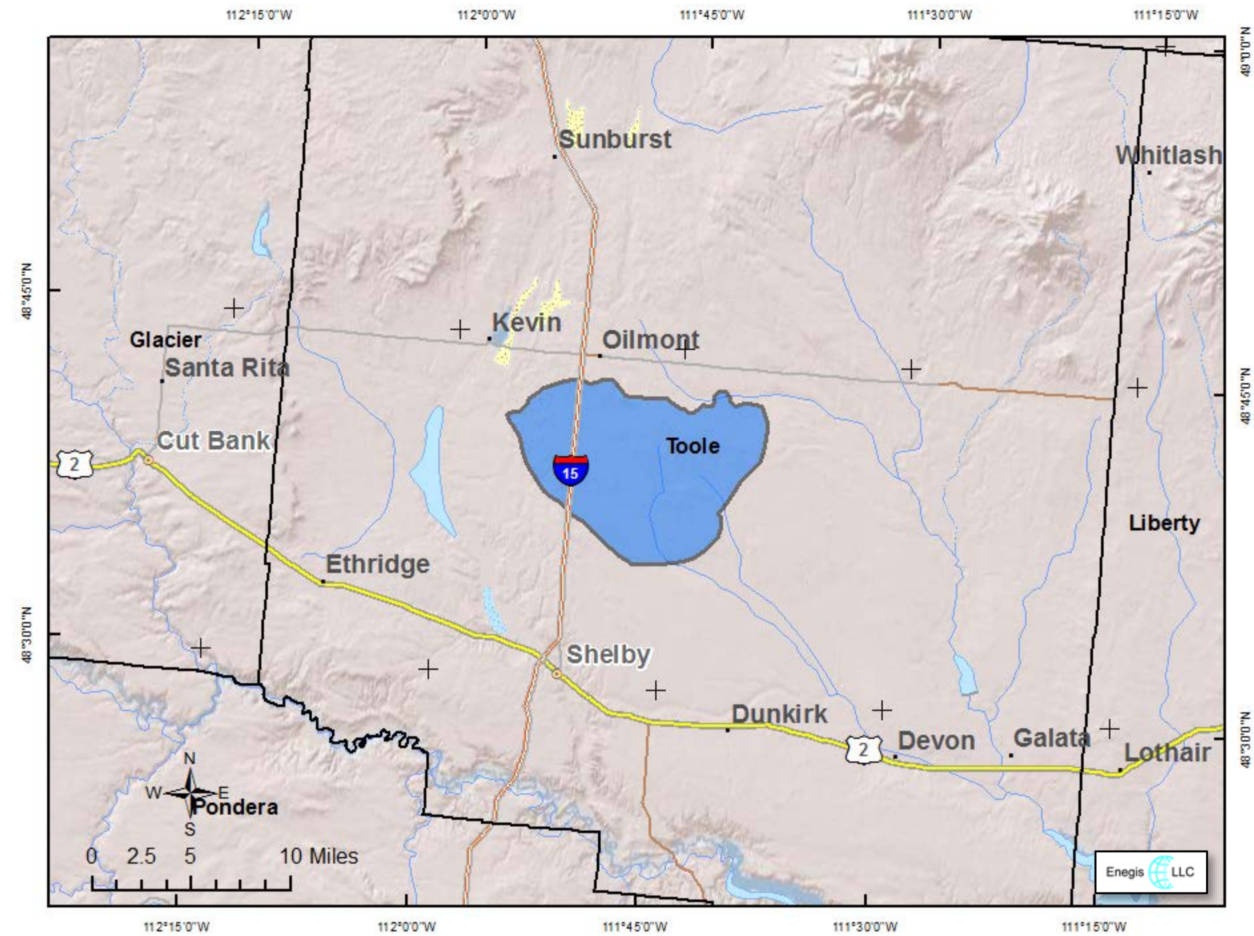
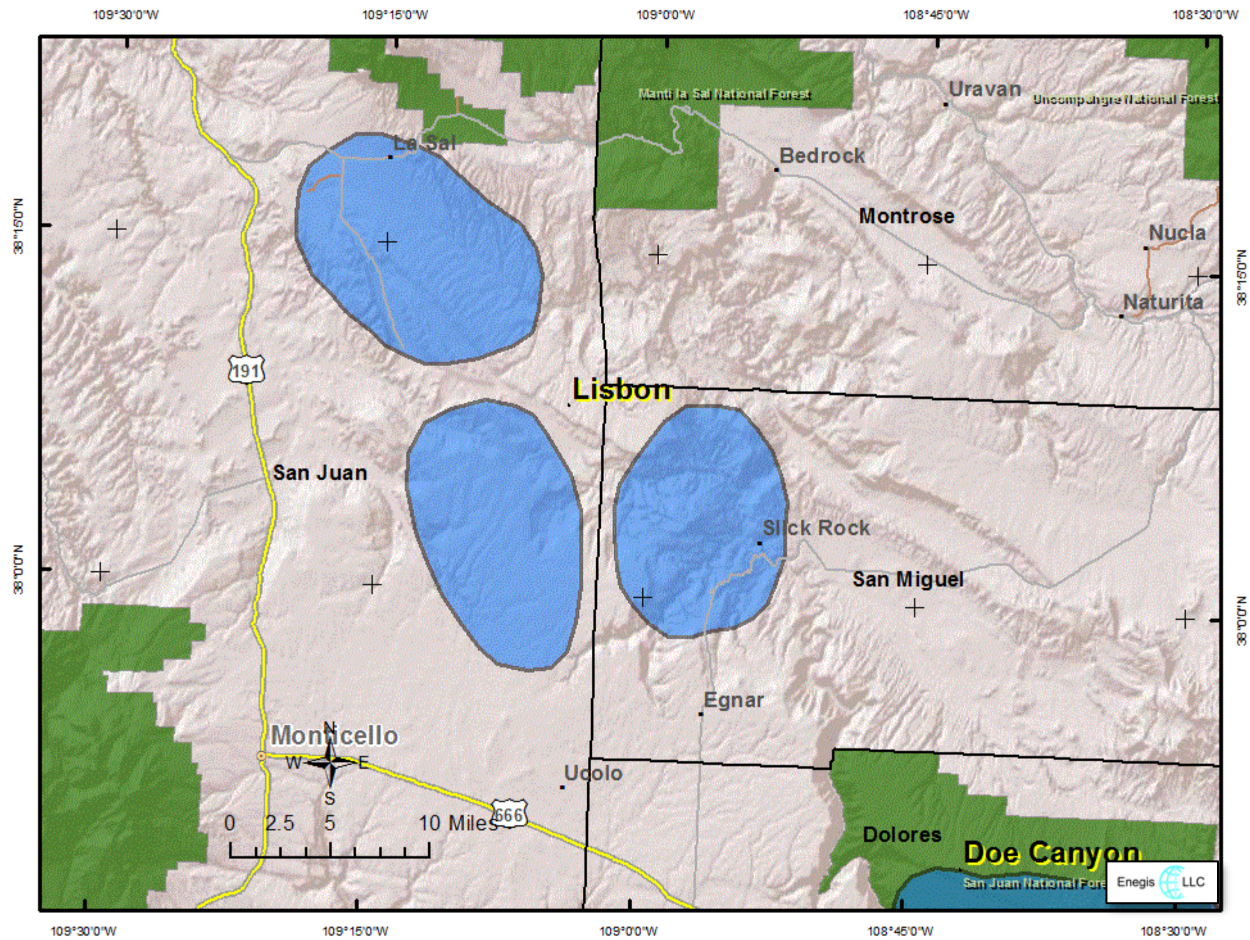


Exhibit A1-12 Lisbon CO_2 fields



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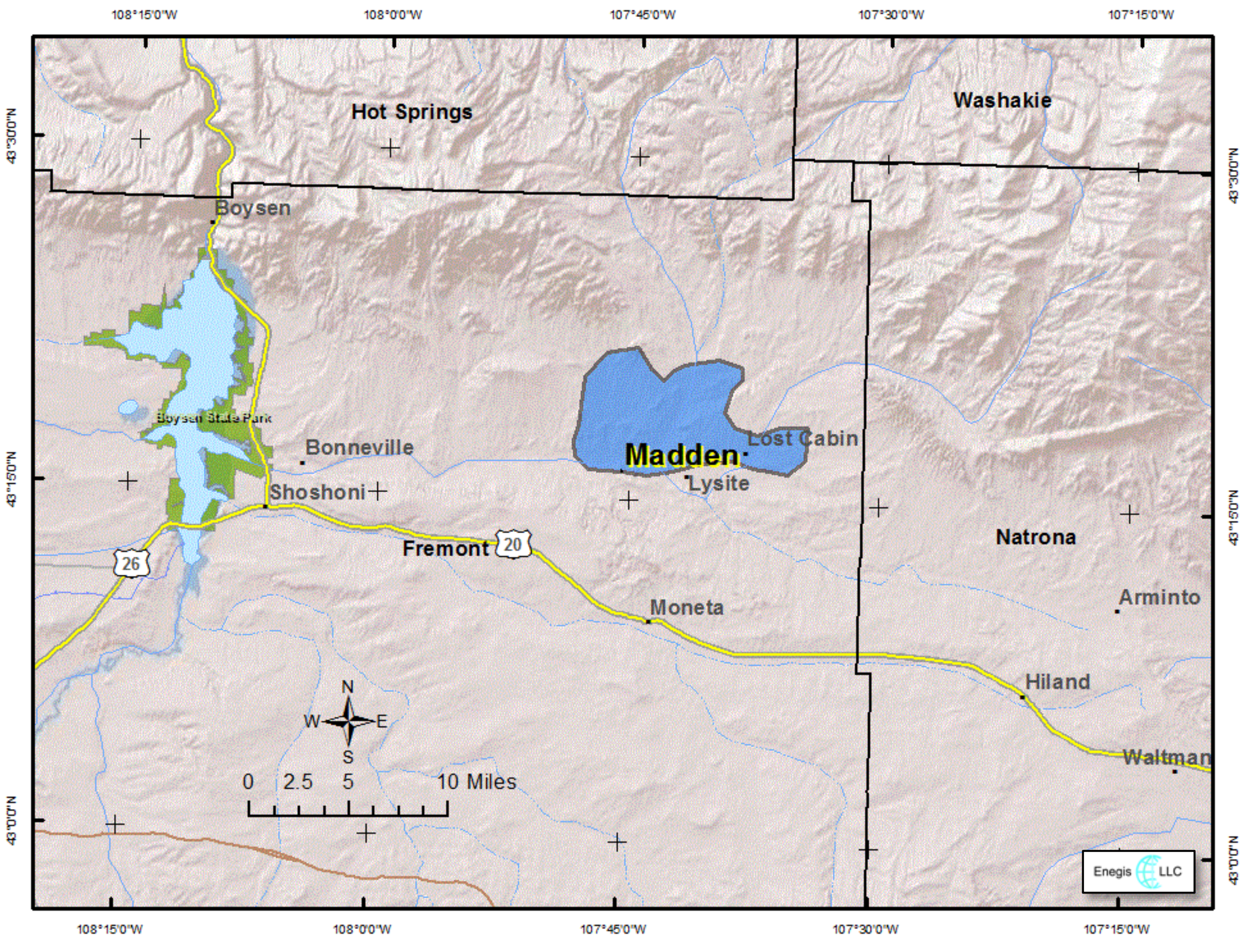


Exhibit A1-14 McCallum CO_2 field

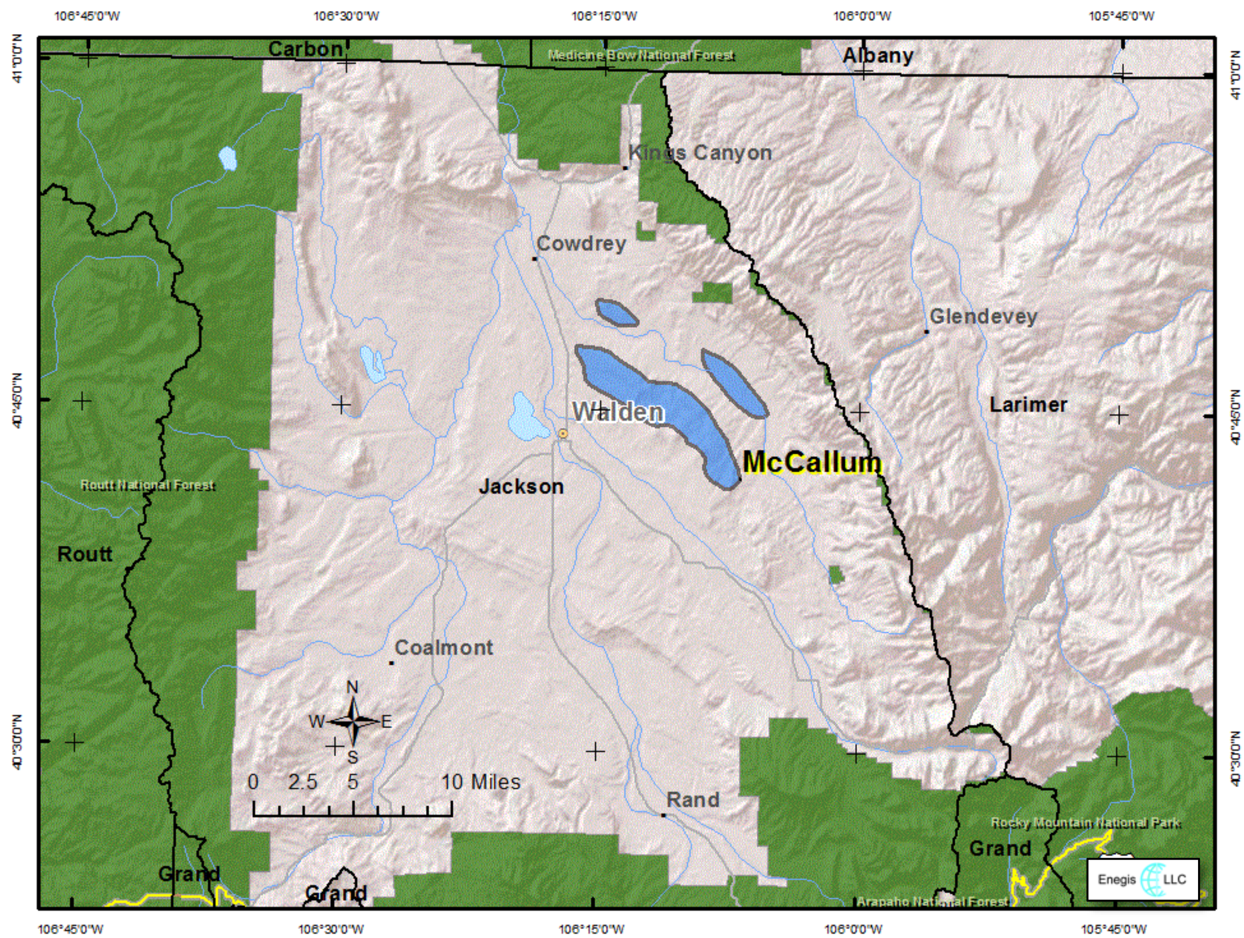


Exhibit A1-15 McElmo Dome CO_2 fields

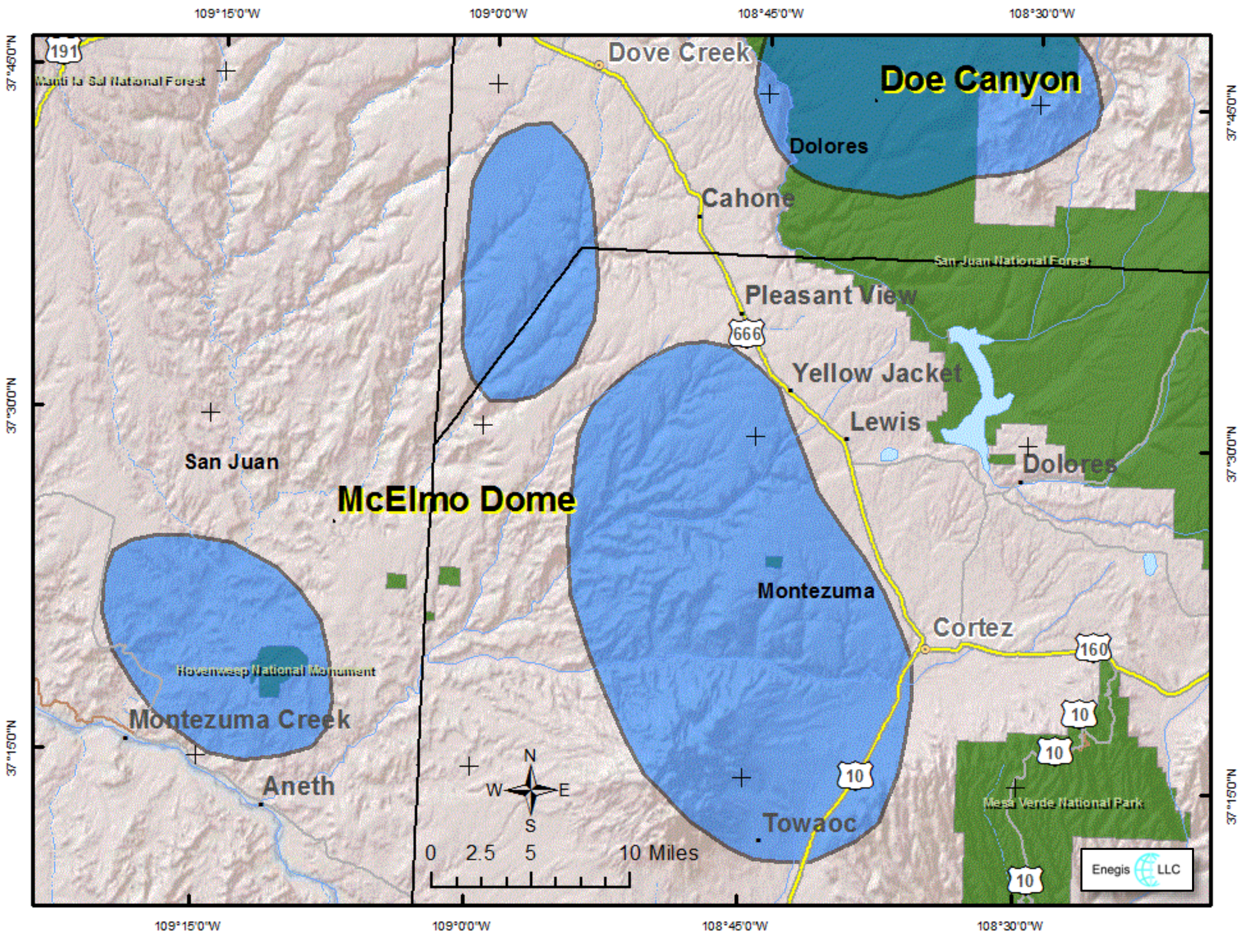


Exhibit A1-16 Oakdale and Sheep Mountain CO_2 fields

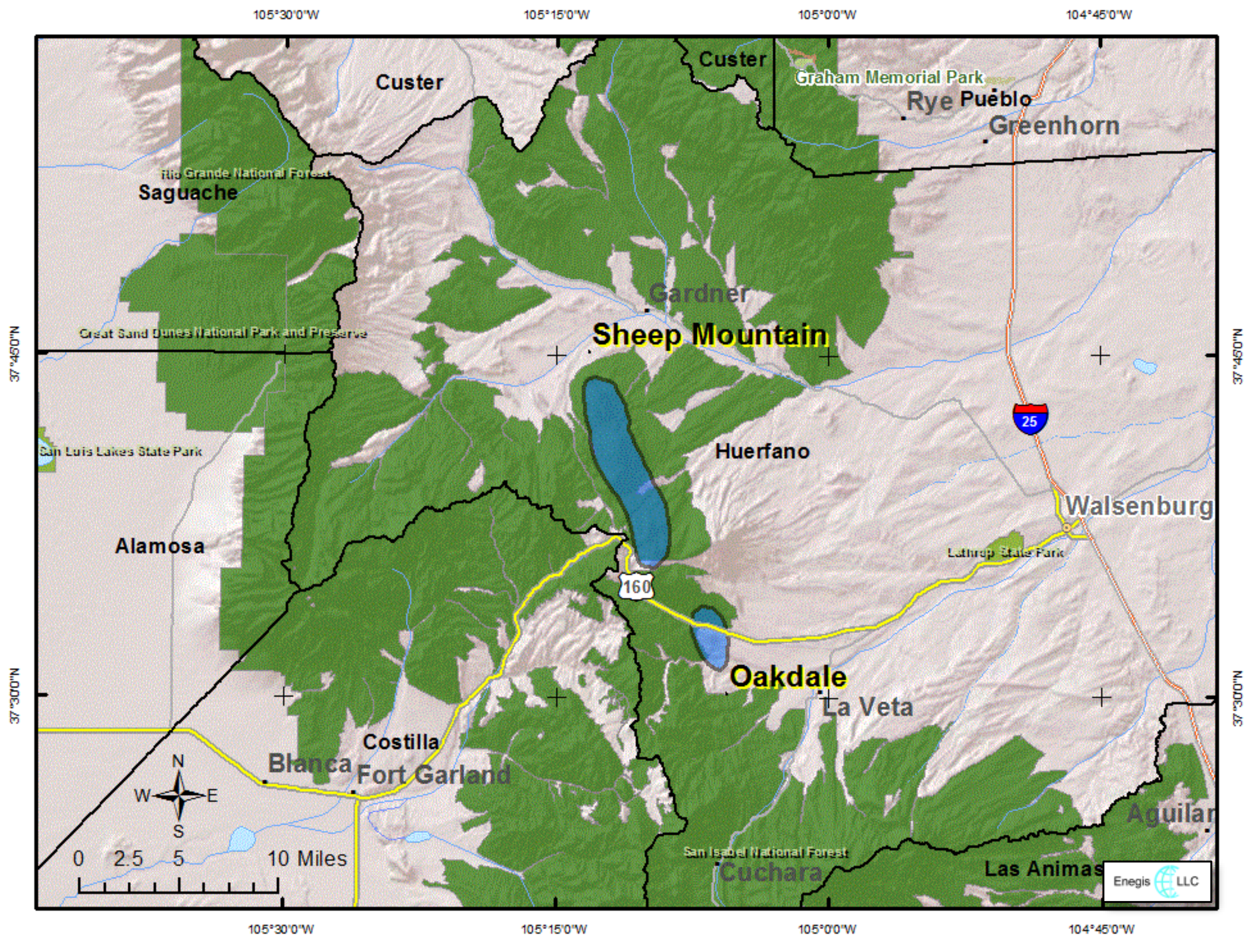


Exhibit A1-17 St. Johns/Springerville CO_2 field

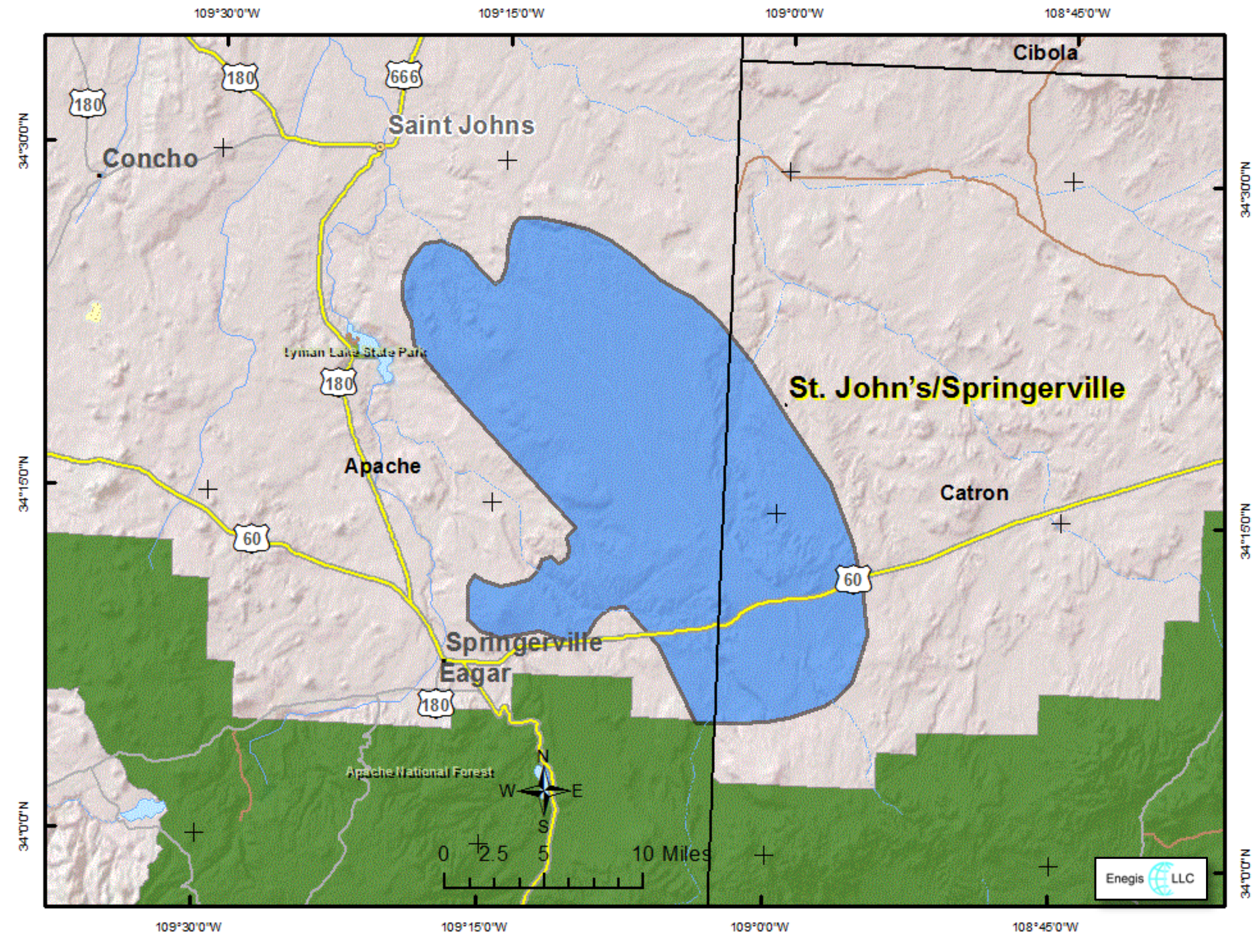
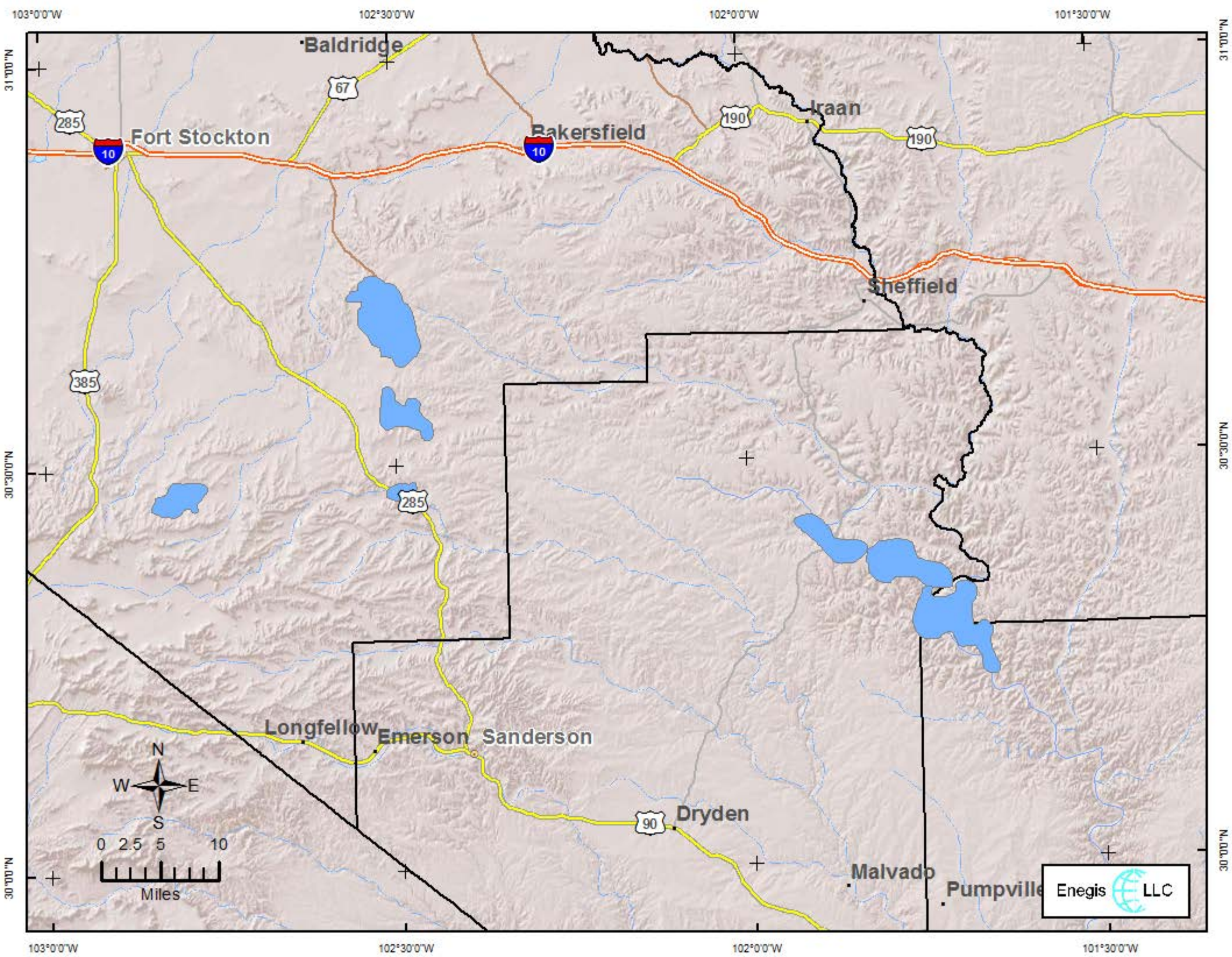


Exhibit A1-18 Val Verde Basin CO_2 fields



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Appendix 2 Disaggregated Field Parameters and Results from CREAM[1]

[1] Also available in accompanying spreadsheet

Exhibit A2-1 GIIP estimates from CREAM

Area or Field	Reservoir	State	Gas Initially in Place (GIIP)																			
			Region	Status	Area	Net Thick	φ	Surf Elev	Drill Depth	Rsrvr Temp	Rsrvr Press	Fm Vol Fctr	Sw	CO_2 Conc	CH_4 Conc	N_2 Conc	He Conc	H_2S Conc	Probability	NG GIIP	CO_2 GIIP
					Acres	Ft	%	Ft	Ft	Deg F	Psi	Rcf/Scf	%	%	%	%	%	%	%	Bcf	Bcf
Imperial	Cenozoic Ss	CA	Other	Inactive	1,725	230	12%	(55)	591	245	339	0.010	20%	95%	0%	0%	0%	0%	100%	165.9	157.6
Doe Canyon	Leadville, Ouray	CO	Colorado Plateau	Under development	82,078	60	10%	2500	9,000	213	3,960	0.003	20%	95%	0%	0%	0%	0%	100%	5,363.0	5,094.8
McCallum	Dakota Ss, Lakota Ss	CO	Rocky Mountains	Producing	15,250	100	20%	8200	5,500	120	2,316	0.004	20%	92%	0%	0%	0.11%	0%	100%	3,036.8	2,796.9
McElmo Dome	Leadville, Elbert	CO, UT	Colorado Plateau	Producing	201,500	95	12%	2000	8,000	196	3,520	0.003	20%	98%	0%	2%	0.07%	0%	100%	30,788.2	30,095.5
Oakdale	Dakota, Entrada, dike	CO	Rocky Mountains	Discovered	3,400	250	19%	8200	6,000	179	2,790	0.004	20%	72%	28%	0%	0.03%	0%	100%	1,608.0	1,152.9
Sheep Mountain	Dakota, Entrada	CO	Rocky Mountains	Producing	12,200	145	20%	8200	5,000	157	2,165	0.004	20%	97%	1%	2%	0.03%	0%	100%	3,161.3	3,066.5
Jackson Dome	Smackover, Norphlet Fms	MS	Other	Producing*	90,000	185	13%	110	15,500	339	7,000	0.003	20%	90%	5%	0%	0.00%	5%	100%	26,938.7	24,244.9
Kevin Dome	Common Duperow Fm (Uppr & Lwr)	MT	Rocky Mountains	Discovered	280,000	75	9%	3400	3,600	91	1,239	0.005	20%	88%	0%	12%	0%	0%	100%	12,979.2	11,421.7
Kevin Dome	Unique Lower Duperow Fm	MT	Rocky Mountains	Discovered	160,000	25	9%	3400	3,600	94	1,311	0.005	20%	88%	0%	12%	0%	0%	100%	2,729.8	2,402.2
Bravo Dome	Yeso Fm-Tubb Ss Mem	NM	Rocky Mountains	Producing	700,000	125	20%	4850	2,550	80	641	0.016	50%	97%	0%	0%	0.02%	0%	100%	23,821.9	23,107.2
Des Moines	Abo Fm	NM	Rocky Mountains	Inactive	58,157	50	20%	2000	2,330	78	137	0.020	20%	99%	0%	0%	0.02%	0%	100%	1,013.3	1,003.2
Estancia	Sandia Fm	NM	Colorado Plateau	Inactive	47,750	65	14%	1900	1,475	81	400	0.015	20%	98%	2%	0%	0.02%	0%	100%	1,009.5	989.3
St. Johns/ Springerville	Supai Fm	NM, AZ	Colorado Plateau	Under development	220,125	75	15%	6900	1,526	88	508	0.009	20%	93%	0%	4%	0.60%	0%	100%	9,588.6	8,917.4
Val Verde Basin	Caballos	TX	Permian Basin	Producing	1,927	550	4%	3000	4,000	116	1,732	0.006	20%	78%	22%	0%	0.01%	0%	100%	263.7	205.7
Val Verde Basin	Caballos, Tesnus	TX	Permian Basin	Producing	6,013	550	4%	3000	8,500	174	3,681	0.003	20%	97%	3%	0%	0.01%	0%	100%	1,773.0	1,719.8
Val Verde Basin	Ellenburg, Simpson, Woodford	TX	Permian Basin	Producing	6,902	650	4%	3000	15,500	230	6,712	0.003	20%	50%	50%	0%	0.01%	0%	100%	1,954.3	977.1
Val Verde Basin	Ellenburg, Simpson, Woodford	TX	Permian Basin	Producing	18,105	650	4%	3000	13,200	220	5,716	0.004	20%	30%	70%	0%	0.01%	0%	100%	4,556.7	1,367.0
Val Verde Basin	Ellenburg, Simpson, Woodford	TX	Permian Basin	Producing	7,353	650	4%	3000	14,500	226	6,279	0.003	20%	55%	45%	0%	0.01%	0%	100%	1,959.6	1,077.8
Val Verde Basin	Ellenburg, Simpson, Woodford	TX	Permian Basin	Producing	12,142	650	4%	3000	14,500	226	6,279	0.004	20%	39%	61%	0%	0.01%	0%	100%	3,056.0	1,191.8
Val Verde Basin	Ellenburg, Simpson, Woodford	TX	Permian Basin	Producing	17,235	650	4%	3000	14,500	226	6,279	0.004	20%	20%	80%	0%	0.01%	0%	100%	4,109.3	821.9
Escalante Anticline	Chinle-Shinarump Mem	UT	Colorado Plateau	Discovered	37,000	225	6%	6800	1,371	79	638	0.018	20%	95%	0%	4%	0.01%	0%	100%	967.0	914.8
Escalante Anticline	Moenkopi-Timpoweap Mem	UT	Colorado Plateau	Discovered	37,000	80	5%	6800	2,267	95	1,054	0.009	20%	95%	0%	4%	0.01%	0%	100%	527.5	499.0

Area or Field	Reservoir	State	Gas Initially in Place (GIIP)																		
			Region	Status	Area	Net Thick	φ	Surf Elev	Drill Depth	Rsrvr Temp	Rsrvr Press	Fm Vol Fctr	Sw	CO_2 Conc	CH_4 Conc	N_2 Conc	He Conc	H_2S Conc	Probability	NG GIIP	CO_2 GIIP
					Acres	Ft	%	Ft	Ft	Deg F	Psi	Rcf/Scf	%	%	%	%	%	%	%	Bcf	Bcf
Escalante Anticline	Kaibab Ls	UT	Colorado Plateau	Discovered	37,000	125	7%	6800	2,362	97	1,098	0.008	20%	95%	0%	4%	0.01%	0%	100%	1,410.3	1,334.1
Escalante Anticline	Toroweap Ss/White Rim SS	UT	Colorado Plateau	Discovered	37,000	195	6%	6800	2,582	100	1,201	0.006	20%	95%	0%	4%	0.01%	0%	100%	2,514.3	2,378.5
Escalante Anticline	Cedar Mesa SS	UT	Colorado Plateau	Discovered	37,000	150	13%	6800	3,150	110	1,465	0.005	20%	95%	0%	4%	0.01%	0%	100%	5,238.1	4,955.2
Farnham Anticline	Navajo, Sinbad, White Rim	UT	Colorado Plateau	Discovered	3,600	40	12%	5600	4,000	110	2,200	0.002	35%	99%	0%	1%	0%	0%	100%	203.9	201.8
Gordon Creek	Moenkopi Fm-Sinbad Ls	UT	Colorado Plateau	Discovered	8,400	20	6%	6500	10,958	192	6,242	0.002	20%	99%	0%	0%	0%	0%	100%	159.7	158.7
Gordon Creek	White Rim Ss	UT	Colorado Plateau	Discovered	8,400	150	9%	6500	12,795	217	6,609	0.003	20%	99%	1%	0%	0%	0%	100%	1,580.7	1,561.7
Lisbon	Leadville LS	UT	Colorado Plateau	Discovered	3,200	75	12%	6600	9,600	224	3,200	0.004	20%	90%	0%	0%	0%	0%	100%	264.1	237.7
Woodside	White Rim Fm	UT	Colorado Plateau	Discovered	12,800	45	9%	5200	3,500	103	1,628	0.005	20%	32%	0%	62%	0%	0%	100%	347.4	111.2
Indian Creek	Tuscarora Fm	WV	Other	Producing	18,497	10	10%	1400	6,674	126	3,000	0.004	43%	66%	30%	4%	0.15%	0%	100%	129.1	85.2
Big Piney-LaBarge Basinal	Madison Ls Fm	WY	Rocky Mountains	Producing*	29,670	275	9%	7200	15,700	225	6,594	0.003	15%	82%	11%	4%	0.48%	3%	100%	10,070.3	8,267.5
Big Piney-LaBarge Basinal	Madison Ls Fm	WY	Rocky Mountains	Producing*	7,554	275	9%	7200	14,700	211	6,174	0.003	15%	82%	11%	4%	0.48%	3%	100%	2,662.5	2,183.6
Big Piney-LaBarge Basinal	Madison Ls Fm	WY	Rocky Mountains	Producing*	74,234	275	9%	7200	16,700	239	7,014	0.003	15%	97%	2%	1%	0.57%	0%	100%	27,210.9	26,374.6
Big Piney-LaBarge Basinal	Madison Ls Fm	WY	Rocky Mountains	Producing*	2,078	275	9%	7200	15,700	225	6,594	0.003	15%	92%	5%	2%	0.54%	1%	100%	761.6	700.3
Big Piney-LaBarge Basinal	Madison Ls Fm	WY	Rocky Mountains	Producing*	66,555	275	9%	7200	16,700	239	7,014	0.003	15%	92%	5%	2%	0.54%	1%	100%	24,396.3	22,433.8
Big Piney-LaBarge Basinal	Madison Ls Fm	WY	Rocky Mountains	Producing*	67,921	275	9%	7200	15,700	225	6,594	0.003	15%	87%	8%	3%	0.51%	2%	100%	23,939.5	20,823.9
Big Piney-LaBarge Basinal	Madison Ls Fm	WY	Rocky Mountains	Producing*	11,083	275	9%	7200	16,700	239	7,014	0.003	15%	87%	8%	3%	0.51%	2%	100%	3,906.4	3,398.0
Big Piney-LaBarge Basinal	Madison Ls Fm	WY	Rocky Mountains	Producing*	8,628	275	9%	7200	14,700	211	6,174	0.003	15%	87%	8%	3%	0.51%	2%	100%	3,162.5	2,751.0
Big Piney-LaBarge Basinal	Madison Ls Fm	WY	Rocky Mountains	Producing*	13,915	275	9%	7200	15,700	225	6,594	0.003	15%	77%	14%	5%	0.45%	4%	100%	4,397.1	3,387.7
Big Piney-LaBarge Basinal	Madison Ls Fm	WY	Rocky Mountains	Producing*	35,556	275	9%	7200	14,700	211	6,174	0.003	15%	77%	14%	5%	0.45%	4%	100%	10,861.1	8,367.9
Big Piney-LaBarge Basinal	Madison Ls Fm	WY	Rocky Mountains	Producing*	33,259	275	9%	7200	14,700	211	6,174	0.003	15%	72%	17%	6%	0.42%	5%	100%	9,831.6	7,086.0
Big Piney-LaBarge Basinal	Madison Ls Fm	WY	Rocky Mountains	Producing*	17,321	275	9%	7200	13,700	197	5,754	0.003	15%	72%	17%	6%	0.42%	5%	100%	4,960.1	3,575.0
Big Piney-LaBarge Basinal	Madison Ls Fm	WY	Rocky Mountains	Producing*	15,515	275	9%	7200	13,700	197	5,754	0.003	15%	67%	20%	8%	0.39%	5%	100%	4,308.3	2,891.0
Big Piney-LaBarge Basinal	Madison Ls Fm	WY	Rocky Mountains	Producing*	4,577	275	9%	7200	13,700	197	5,754	0.003	15%	62%	23%	9%	0.37%	6%	100%	1,233.7	766.6
Big Piney-LaBarge Basinal	Madison Ls Fm	WY	Rocky Mountains	Producing*	5	275	9%	7200	15,700	225	6,594	0.003	15%	82%	11%	4%	0.48%	3%	100%	1.6	1.3
Big Piney-LaBarge Basinal	Madison Ls Fm	WY	Rocky Mountains	Producing*	5	275	9%	7200	15,700	225	6,594	0.003	15%	77%	14%	5%	0.45%	4%	100%	1.6	1.2
Big Piney-LaBarge Foreland	Madison Ls Fm	WY	Rocky Mountains	Producing	11,177	275	9%	9000	17,500	340	7,350	0.003	15%	82%	11%	4%	0.55%	3%	100%	3,304.1	2,707.7
Big Piney-LaBarge Foreland	Madison Ls Fm	WY	Rocky Mountains	Producing	581	275	9%	9000	16,500	326	6,930	0.003	15%	82%	11%	4%	0.55%	3%	100%	171.7	140.7
Big Piney-LaBarge Foreland	Madison Ls Fm	WY	Rocky Mountains	Producing	12,491	275	9%	9000	18,500	353	7,770	0.003	15%	97%	2%	1%	0.65%	0%	100%	4,402.5	4,263.8
Big Piney-LaBarge Foreland	Madison Ls Fm	WY	Rocky Mountains	Producing	2,185	275	9%	9000	17,500	340	7,350	0.003	15%	92%	5%	2%	0.61%	1%	100%	741.7	681.5
Big Piney-LaBarge	Madison Ls	WY	Rocky	Producing	6,970	275	9%	9000	18,500	353	7,770	0.003	15%	92%	5%	2%	0.61%	1%	100%	2,365.7	2,173.7

Area or Field	Reservoir	State	Gas Initially in Place (GIIP)																		
			Region	Status	Area	Net Thick	φ	Surf Elev	Drill Depth	Rsrvr Temp	Rsrvr Press	Fm Vol Fctr	Sw	CO_2 Conc	CH_4 Conc	N_2 Conc	He Conc	H_2S Conc	Probability	NG GIIP	CO_2 GIIP
					Acres	Ft	%	Ft	Ft	Deg F	Psi	Rcf/Scf	%	%	%	%	%	%	%	Bcf	Bcf
Foreland	Fm		Mountains																		
Big Piney-LaBarge Foreland	Madison Ls Fm	WY	Rocky Mountains	Producing	5,598	275	9%	9000	17,500	340	7,350	0.003	15%	87%	8%	3%	0.58%	2%	100%	1,832.0	1,592.3
Big Piney-LaBarge Foreland	Madison Ls Fm	WY	Rocky Mountains	Producing	6,308	275	9%	9000	17,500	340	7,350	0.003	15%	77%	14%	5%	0.51%	4%	100%	1,864.8	1,435.6
Big Piney-LaBarge Foreland	Madison Ls Fm	WY	Rocky Mountains	Producing	13,870	275	9%	9000	16,500	326	6,930	0.003	15%	77%	14%	5%	0.51%	4%	100%	4,236.9	3,261.7
Big Piney-LaBarge Foreland	Madison Ls Fm	WY	Rocky Mountains	Producing	125	275	9%	9000	15,500	312	6,510	0.003	15%	77%	14%	5%	0.51%	4%	100%	36.8	28.3
Big Piney-LaBarge Foreland	Madison Ls Fm	WY	Rocky Mountains	Producing	15	275	9%	9000	17,500	340	7,350	0.003	15%	72%	17%	6%	0.48%	5%	100%	4.2	3.0
Big Piney-LaBarge Foreland	Madison Ls Fm	WY	Rocky Mountains	Producing	9,524	275	9%	9000	16,500	326	6,930	0.003	15%	72%	17%	6%	0.48%	5%	100%	2,727.3	1,964.1
Big Piney-LaBarge Foreland	Madison Ls Fm	WY	Rocky Mountains	Producing	9,999	275	9%	9000	15,500	312	6,510	0.003	15%	72%	17%	6%	0.48%	5%	100%	2,955.8	2,128.7
Big Piney-LaBarge Foreland	Madison Ls Fm	WY	Rocky Mountains	Producing	23	275	9%	9000	14,500	298	6,090	0.003	15%	72%	17%	6%	0.48%	5%	100%	7.0	5.0
Big Piney-LaBarge Foreland	Madison Ls Fm	WY	Rocky Mountains	Producing	682	275	9%	9000	16,500	326	6,930	0.003	15%	67%	20%	8%	0.45%	5%	100%	189.4	127.0
Big Piney-LaBarge Foreland	Madison Ls Fm	WY	Rocky Mountains	Producing	26,231	275	9%	9000	15,500	312	6,510	0.004	15%	67%	20%	8%	0.45%	5%	100%	6,496.8	4,356.1
Big Piney-LaBarge Foreland	Madison Ls Fm	WY	Rocky Mountains	Producing	2,171	275	9%	9000	14,500	298	6,090	0.004	15%	67%	20%	8%	0.45%	5%	100%	568.3	381.0
Big Piney-LaBarge Foreland	Madison Ls Fm	WY	Rocky Mountains	Producing	16,479	275	9%	9000	15,500	312	6,510	0.004	15%	62%	23%	9%	0.41%	6%	100%	3,775.3	2,343.8
Big Piney-LaBarge Foreland	Madison Ls Fm	WY	Rocky Mountains	Producing	11,140	275	9%	9000	14,500	298	6,090	0.004	15%	62%	23%	9%	0.41%	6%	100%	2,759.2	1,713.0
Big Piney-LaBarge Foreland	Madison Ls Fm	WY	Rocky Mountains	Producing	2,257	275	9%	9000	14,500	298	6,090	0.004	15%	57%	26%	10%	0.38%	7%	100%	559.1	319.3
Big Piney-LaBarge Foreland	Madison Ls Fm	WY	Rocky Mountains	Producing	2	275	9%	9000	17,500	340	7,350	0.003	15%	82%	11%	4%	0.55%	3%	100%	0.6	0.5
Big Piney-LaBarge Foreland	Madison Ls Fm	WY	Rocky Mountains	Producing	2	275	9%	9000	17,500	340	7,350	0.003	15%	77%	14%	5%	0.51%	4%	100%	0.6	0.5
Big Piney-LaBarge Highland	Madison Ls Fm	WY	Rocky Mountains	Discovered	31,651	275	9%	10000	18,500	353	7,770	0.003	15%	82%	11%	4%	0.50%	3%	100%	9,356.3	7,671.9
Big Piney-LaBarge Highland	Madison Ls Fm	WY	Rocky Mountains	Discovered	23	275	9%	10000	17,500	340	7,350	0.003	15%	82%	11%	4%	0.50%	3%	100%	6.9	5.7
Big Piney-LaBarge Highland	Madison Ls Fm	WY	Rocky Mountains	Discovered	221	275	9%	10000	18,500	353	7,770	0.002	15%	97%	2%	1%	0.59%	0%	100%	84.5	81.9
Big Piney-LaBarge Highland	Madison Ls Fm	WY	Rocky Mountains	Discovered	14,951	275	9%	10000	19,500	367	8,190	0.003	15%	97%	2%	1%	0.59%	0%	100%	5,074.4	4,917.4
Big Piney-LaBarge Highland	Madison Ls Fm	WY	Rocky Mountains	Discovered	5,553	275	9%	10000	18,500	353	7,770	0.003	15%	92%	5%	2%	0.56%	1%	100%	1,884.6	1,732.6
Big Piney-LaBarge Highland	Madison Ls Fm	WY	Rocky Mountains	Discovered	6,947	275	9%	10000	19,500	367	8,190	0.003	15%	92%	5%	2%	0.56%	1%	100%	2,273.7	2,090.3
Big Piney-LaBarge Highland	Madison Ls Fm	WY	Rocky Mountains	Discovered	7,696	275	9%	10000	18,500	353	7,770	0.003	15%	87%	8%	3%	0.53%	2%	100%	2,518.9	2,190.6
Big Piney-LaBarge Highland	Madison Ls Fm	WY	Rocky Mountains	Discovered	11,443	275	9%	10000	18,500	353	7,770	0.003	15%	77%	14%	5%	0.47%	4%	100%	3,177.8	2,447.8
Big Piney-LaBarge Highland	Madison Ls Fm	WY	Rocky Mountains	Discovered	19,125	275	9%	10000	17,500	340	7,350	0.003	15%	77%	14%	5%	0.47%	4%	100%	5,311.0	4,090.9
Big Piney-LaBarge Highland	Madison Ls Fm	WY	Rocky Mountains	Discovered	8,006	275	9%	10000	17,500	340	7,350	0.003	15%	72%	17%	6%	0.44%	5%	100%	2,223.3	1,602.1
Big Piney-LaBarge Highland	Madison Ls Fm	WY	Rocky Mountains	Discovered	12,342	275	9%	10000	16,500	326	6,930	0.003	15%	72%	17%	6%	0.44%	5%	100%	3,326.4	2,396.9
Big Piney-LaBarge Highland	Madison Ls Fm	WY	Rocky Mountains	Discovered	6,585	275	9%	10000	16,500	326	6,930	0.004	15%	67%	20%	8%	0.41%	5%	100%	1,724.1	1,156.7
Madden	Madison Fm	WY	Rocky Mountains	Producing*	79,500	175	15%	5350	23,700	335	11,021	0.004	20%	20%	67%	0%	0%	12%	100%	19,137.7	3,827.5

Exhibit A2-2 Accessible TRR estimates from CREAM

Area or Field	Accessible Technically Recoverable Resources (TRR)										
	Recovery Factor	NG TRR	Accessible portion	Accessible NG TRR	Accessible CO_2 TRR	No. wells	NG TRR /well	NG EUR Tier, Average EUR Per Well			
								10%	20%	30%	40%
	%	Bcf	%	Bcf	Bcf		Bcf	Bcf	Bcf	Bcf	Bcf
Imperial	65%	107.8	80%	86.3	82.0	25	3.45	5.6	5.3	3.6	1.9
Doe Canyon	70%	3,754.1	75%	2,815.6	2,674.8	96	29.3	47.6	44.7	30.5	16.2
McCallum	70%	2,125.7	90%	1,913.2	1,762.0	21	91.1	148.0	138.8	94.7	50.3
McElmo Dome	70%	21,551.7	65%	14,008.6	13,693.4	205	68.3	111.0	104.1	71.1	37.7
Oakdale	65%	1,045.2	80%	836.2	599.5	4	209.0	339.5	318.6	217.4	115.4
Sheep Mountain	65%	2,054.9	80%	1,643.9	1,594.6	15	109.6	178.0	167.0	114.0	60.5
Jackson Dome	70%	18,857.1	95%	17,914.3	16,122.8	134	133.7	217.1	203.7	139.0	73.8
Kevin Dome	75%	9,734.4	95%	9,247.7	8,138.0	416	22.2	36.1	33.9	23.1	12.3
Kevin Dome	75%	2,047.3	95%	1,945.0	1,711.6	238	8.2	13.3	12.5	8.5	4.5
Bravo Dome	65%	15,484.2	90%	13,935.8	13,517.7	984	14.2	23.0	21.6	14.7	7.8
Des Moines	65%	658.7	90%	592.8	586.9	82	7.2	11.7	11.0	7.5	4.0
Estancia	60%	605.7	95%	575.4	563.9	71	8.1	13.2	12.4	8.4	4.5
St. Johns/Springerville	70%	6,712.1	80%	5,369.6	4,993.8	275	19.5	41.0	25.1	20.3	10.8
Val Verde Basin	70%	184.6	95%	175.4	136.8	3	58.5	95.0	89.1	60.8	32.3
Val Verde Basin	70%	1,241.1	95%	1,179.1	1,143.7	9	131.0	212.8	199.7	136.2	72.3
Val Verde Basin	70%	1,368.0	95%	1,299.6	649.8	10	130.0	211.1	198.1	135.1	71.7
Val Verde Basin	70%	3,189.7	95%	3,030.2	909.1	27	112.2	182.3	171.0	116.7	61.9
Val Verde Basin	70%	1,371.7	95%	1,303.1	716.7	11	118.5	192.4	180.5	123.2	65.4
Val Verde Basin	70%	2,139.2	95%	2,032.2	792.6	18	112.9	183.4	172.1	117.4	62.3
Val Verde Basin	70%	2,876.5	95%	2,732.7	546.5	26	105.1	170.7	160.2	109.3	58.0
Escalante Anticline	55%	531.9	45%	239.3	226.4	26	9.2	15.0	14.0	9.6	5.1
Escalante Anticline	55%	290.1	45%	130.5	123.5	26	5.0	8.2	7.7	5.2	2.8
Escalante Anticline	55%	775.6	45%	349.0	330.2	26	13.4	21.8	20.5	14.0	7.4
Escalante Anticline	55%	1,382.9	45%	622.3	588.7	26	23.9	38.9	36.5	24.9	13.2
Escalante Anticline	55%	2,880.9	45%	1,296.4	1,226.4	26	49.9	81.0	76.0	51.9	27.5
Farnham Anticline	70%	142.7	45%	64.2	63.6	3	21.4	34.8	32.6	22.3	11.8
Gordon Creek	65%	103.8	90%	93.4	92.8	12	7.8	12.6	11.9	8.1	4.3
Gordon Creek	65%	1,027.5	90%	924.7	913.6	12	77.1	125.2	117.4	80.1	42.5
Lisbon	70%	184.9	85%	157.1	141.4	4	39.3	63.8	59.9	40.9	21.7
Woodside	60%	208.4	90%	187.6	60.0	18	10.4	16.9	15.9	10.8	5.8
Indian Creek	70%	90.4	95%	85.8	56.7	27	3.2	5.2	4.8	3.3	1.8
Big Piney-LaBarge Basinal	70%	7,049.2	85%	5,991.8	4,919.2	39	153.6	249.5	234.2	159.8	84.8
Big Piney-LaBarge Basinal	70%	1,863.7	85%	1,584.2	1,299.3	10	158.4	257.3	241.4	164.7	87.4
Big Piney-LaBarge Basinal	70%	19,047.6	85%	16,190.5	15,692.9	99	163.5	265.6	249.2	170.1	90.3
Big Piney-LaBarge Basinal	70%	533.1	85%	453.1	416.7	3	151.0	245.3	230.2	157.1	83.4
Big Piney-LaBarge Basinal	70%	17,077.4	85%	14,515.8	13,348.1	88	165.0	267.9	251.4	171.5	91.0
Big Piney-LaBarge Basinal	70%	16,757.7	85%	14,244.0	12,390.2	90	158.3	257.1	241.2	164.6	87.4
Big Piney-LaBarge Basinal	70%	2,734.5	85%	2,324.3	2,021.8	15	155.0	251.7	236.2	161.1	85.5
Big Piney-LaBarge Basinal	70%	2,213.8	85%	1,881.7	1,636.8	11	171.1	277.9	260.7	177.9	94.4
Big Piney-LaBarge Basinal	70%	3,077.9	85%	2,616.2	2,015.7	18	145.3	236.1	221.5	151.2	80.2
Big Piney-LaBarge Basinal	70%	7,602.8	85%	6,462.4	4,978.9	47	137.5	223.3	209.6	143.0	75.9
Big Piney-LaBarge Basinal	70%	6,882.1	85%	5,849.8	4,216.2	44	133.0	215.9	202.6	138.3	73.4
Big Piney-LaBarge Basinal	70%	3,472.1	85%	2,951.3	2,127.1	23	128.3	208.4	195.6	133.4	70.8
Big Piney-LaBarge Basinal	70%	3,015.8	85%	2,563.5	1,720.2	21	122.1	198.3	186.0	126.9	67.4
Big Piney-LaBarge Basinal	70%	863.6	85%	734.1	456.1	6	122.3	198.7	186.5	127.2	67.5
Big Piney-LaBarge Basinal	70%	1.1	85%	1.0	0.8	-	-	-	-	-	-
Big Piney-LaBarge Basinal	70%	1.1	85%	0.9	0.7	-	-	-	-	-	-
Big Piney-LaBarge Foreland	70%	2,312.9	80%	1,850.3	1,516.3	14	132.2	214.7	201.4	137.4	72.9
Big Piney-LaBarge Foreland	70%	120.2	80%	96.2	78.8	1	96.2	156.2	146.6	100.0	53.1
Big Piney-LaBarge Foreland	70%	3,081.7	80%	2,465.4	2,387.7	16	154.1	250.3	234.8	160.2	85.1
Big Piney-LaBarge Foreland	70%	519.2	80%	415.3	381.6	3	138.4	224.9	211.0	144.0	76.4
Big Piney-LaBarge Foreland	70%	1,656.0	80%	1,324.8	1,217.3	9	147.2	239.1	224.3	153.1	81.2
Big Piney-LaBarge Foreland	70%	1,282.4	80%	1,025.9	891.7	7	146.6	238.1	223.4	152.4	80.9
Big Piney-LaBarge Foreland	70%	1,305.4	80%	1,044.3	803.9	8	130.5	212.0	198.9	135.7	72.1
Big Piney-LaBarge Foreland	70%	2,965.8	80%	2,372.6	1,826.5	17	139.6	226.7	212.7	145.1	77.0
Big Piney-LaBarge Foreland	70%	25.8	80%	20.6	15.9	-	-	-	-	-	-
Big Piney-LaBarge Foreland	70%	2.9	80%	2.3	1.7	-	-	-	-	-	-
Big Piney-LaBarge Foreland	70%	1,909.1	80%	1,527.3	1,099.9	12	127.3	206.7	194.0	132.4	70.3
Big Piney-LaBarge Foreland	70%	2,069.1	80%	1,655.3	1,192.1	12	137.9	224.0	210.2	143.4	76.1
Big Piney-LaBarge Foreland	70%	4.9	80%	3.9	2.8	-	-	-	-	-	-
Big Piney-LaBarge Foreland	70%	132.5	80%	106.0	71.1	1	106.0	172.2	161.6	110.3	58.5
Big Piney-LaBarge Foreland	70%	4,547.7	80%	3,638.2	2,439.4	33	110.2	179.1	168.0	114.7	60.9
Big Piney-LaBarge Foreland	70%	397.8	80%	318.2	213.4	3	106.1	172.3	161.7	110.3	58.6
Big Piney-LaBarge Foreland	70%	2,642.7	80%	2,114.2	1,312.5	21	100.7	163.5	153.4	104.7	55.6
Big Piney-LaBarge Foreland	70%	1,931.4	80%	1,545.2	959.3	14	110.4	179.3	168.2	114.8	60.9

Area or Field	Accessible Technically Recoverable Resources (TRR)										
	Recovery Factor	NG TRR	Accessible portion	Accessible NG TRR	Accessible CO_2 TRR	No. wells	NG TRR /well	NG EUR Tier, Average EUR Per Well			
								10%	20%	30%	40%
	%	Bcf	%	Bcf	Bcf		Bcf	Bcf	Bcf	Bcf	Bcf
Big Piney-LaBarge Foreland	70%	391.4	80%	313.1	178.8	3	104.4	169.5	159.1	108.5	57.6
Big Piney-LaBarge Foreland	70%	0.4	80%	0.3	0.3	-	-	-	-	-	-
Big Piney-LaBarge Foreland	70%	0.4	80%	0.3	0.3	-	-	-	-	-	-
Big Piney-LaBarge Highland	70%	6,549.4	30%	1,964.8	1,611.1	15	131.0	212.8	199.6	136.2	72.3
Big Piney-LaBarge Highland	70%	4.8	30%	1.5	1.2	-	-	-	-	-	-
Big Piney-LaBarge Highland	70%	59.2	30%	17.8	17.2	-	-	-	-	-	-
Big Piney-LaBarge Highland	70%	3,552.1	30%	1,065.6	1,032.6	7	152.2	247.3	232.0	158.3	84.0
Big Piney-LaBarge Highland	70%	1,319.2	30%	395.8	363.8	3	131.9	214.3	201.1	137.2	72.8
Big Piney-LaBarge Highland	70%	1,591.6	30%	477.5	439.0	3	159.2	258.5	242.6	165.5	87.8
Big Piney-LaBarge Highland	70%	1,763.2	30%	529.0	460.0	4	132.2	214.8	201.5	137.5	73.0
Big Piney-LaBarge Highland	70%	2,224.4	30%	667.3	514.0	5	133.5	216.8	203.4	138.8	73.7
Big Piney-LaBarge Highland	70%	3,717.7	30%	1,115.3	859.1	9	123.9	201.3	188.9	128.9	68.4
Big Piney-LaBarge Highland	70%	1,556.3	30%	466.9	336.4	4	116.7	189.6	177.9	121.4	64.4
Big Piney-LaBarge Highland	70%	2,328.5	30%	698.5	503.4	6	116.4	189.1	177.4	121.1	64.3
Big Piney-LaBarge Highland	70%	1,206.9	30%	362.1	242.9	3	120.7	196.0	183.9	125.5	66.6
Madden	70%	13,396.4	95%	12,726.6	2,545.3	118	107.9	175.2	164.4	112.2	59.5

Exhibit A2-3 CO_2 ERR estimates from CREAM (all drilling)

Area or Field	Economically Recoverable Resources (ERR)--Accessible CO_2 All Drilling									
	NPV					CO_2 ERR				
	10%	20%	30%	40%	Total	10%	20%	30%	40%	Total
	$MM	$MM	$MM	$MM	$MM	Bcf	Bcf	Bcf	Bcf	Bcf
Imperial	$ 0	$ (0)	$ (1)	$ (3)	$ (4)	11.3	21.2	21.7	15.4	69.7
Doe Canyon	$ 4	$ 5	$ (36)	$ (108)	$ (135)	369.3	693.0	709.3	502.0	2,273.5
McCallum	$ 14	$ 25	$ 22	$ 6	$ 66	243.3	456.5	467.2	330.7	1,497.7
McElmo Dome	$ 142	$ 254	$ 204	$ 19	$ 619	1,890.5	3,547.8	3,631.2	2,569.8	11,639.2
Oakdale	$ 6	$ 11	$ 10	$ 5	$ 33	82.8	155.3	159.0	112.5	509.6
Sheep Mountain	$ 20	$ 37	$ 39	$ 19	$ 116	220.1	413.1	422.8	299.2	1,355.4
Jackson Dome	$ 116	$ 204	$ 124	$ (82)	$ 362	2,225.9	4,177.2	4,275.4	3,025.7	13,704.1
Kevin Dome	$ 0	$ (11)	$ (86)	$ (222)	$ (318)	1,123.5	2,108.4	2,158.0	1,527.2	6,917.1
Kevin Dome	$ (30)	$ (63)	$ (113)	$ (175)	$ (381)	236.3	443.4	453.9	321.2	1,454.8
Bravo Dome	$ 39	$ 70	$ (47)	$ (287)	$ (225)	1,866.2	3,502.2	3,584.6	2,536.8	11,489.8
Des Moines	$ (2)	$ (5)	$ (15)	$ (32)	$ (54)	81.0	152.0	155.6	110.1	498.8
Estancia	$ 2	$ 3	$ (3)	$ (13)	$ (11)	77.9	146.1	149.5	105.8	479.3
St. Johns/Springerville	$ 53	$ 60	$ 58	$ 5	$ 176	891.4	1,091.9	1,324.2	937.1	4,244.6
Val Verde Basin	$ 1	$ 2	$ 1	$ 0	$ 4	18.9	35.4	36.3	25.7	116.3
Val Verde Basin	$ 16	$ 29	$ 25	$ 12	$ 82	157.9	296.3	303.3	214.6	972.1
Val Verde Basin	$ 1	$ 0	$ (7)	$ (20)	$ (26)	89.7	168.4	172.3	121.9	552.3
Val Verde Basin	$ (8)	$ (17)	$ (35)	$ (62)	$ (122)	125.5	235.5	241.1	170.6	772.7
Val Verde Basin	$ 1	$ 1	$ (6)	$ (19)	$ (23)	98.9	185.7	190.1	134.5	609.2
Val Verde Basin	$ (4)	$ (8)	$ (21)	$ (41)	$ (73)	109.4	205.3	210.2	148.7	673.7
Val Verde Basin	$ (15)	$ (31)	$ (52)	$ (76)	$ (174)	75.5	141.6	144.9	102.6	464.6
Escalante Anticline	$ 1	$ 2	$ (0)	$ (4)	$ (1)	31.3	58.7	60.0	42.5	192.4
Escalante Anticline	$ (1)	$ (3)	$ (6)	$ (11)	$ (21)	17.1	32.0	32.7	23.2	105.0
Escalante Anticline	$ 2	$ 3	$ (0)	$ (6)	$ (1)	45.6	85.5	87.6	62.0	280.7
Escalante Anticline	$ 5	$ 9	$ 6	$ (1)	$ 19	81.3	152.5	156.1	110.5	500.4
Escalante Anticline	$ 15	$ 27	$ 23	$ 9	$ 74	169.3	317.7	325.2	230.2	1,042.4
Farnham Anticline	$ 0	$ 1	$ 0	$ (1)	$ 1	8.8	16.5	16.9	11.9	54.0
Gordon Creek	$ (5)	$ (10)	$ (18)	$ (26)	$ (60)	12.8	24.1	24.6	17.4	78.9
Gordon Creek	$ 8	$ 15	$ 9	$ (7)	$ 25	126.1	236.7	242.3	171.5	776.6
Lisbon	$ (0)	$ (1)	$ (2)	$ (6)	$ (9)	19.5	36.6	37.5	26.5	120.2
Woodside	$ (10)	$ (19)	$ (23)	$ (24)	$ (76)	8.3	15.6	15.9	11.3	51.0
Indian Creek	$ (9)	$ (19)	$ (29)	$ (40)	$ (97)	7.8	14.7	15.0	10.6	48.2
Big Piney-LaBarge Basinal	$ 27	$ 53	$ 28	$ (32)	$ 77	679.1	1,274.5	1,304.4	923.1	4,181.2
Big Piney-LaBarge Basinal	$ 8	$ 14	$ 10	$ (6)	$ 26	179.4	336.6	344.5	243.8	1,104.3
Big Piney-LaBarge Basinal	$ 181	$ 328	$ 320	$ 101	$ 930	2,166.5	4,065.8	4,161.4	2,945.0	13,338.6
Big Piney-LaBarge Basinal	$ 3	$ 6	$ 4	$ (1)	$ 13	57.5	108.0	110.5	78.2	354.2
Big Piney-LaBarge Basinal	$ 110	$ 196	$ 145	$ (18)	$ 434	1,842.8	3,458.3	3,539.6	2,504.9	11,345.6
Big Piney-LaBarge Basinal	$ 88	$ 155	$ 103	$ (39)	$ 307	1,710.6	3,210.1	3,285.6	2,325.2	10,531.4
Big Piney-LaBarge Basinal	$ 13	$ 23	$ 16	$ (10)	$ 43	279.1	523.8	536.1	379.4	1,718.5
Big Piney-LaBarge Basinal	$ 13	$ 23	$ 18	$ (1)	$ 54	226.0	424.1	434.0	307.2	1,391.3
Big Piney-LaBarge Basinal	$ 8	$ 13	$ 3	$ (23)	$ 1	278.3	522.2	534.5	378.3	1,713.3
Big Piney-LaBarge Basinal	$ 21	$ 34	$ 7	$ (57)	$ 5	687.4	1,289.9	1,320.3	934.4	4,231.9
Big Piney-LaBarge Basinal	$ 10	$ 14	$ (12)	$ (71)	$ (59)	582.1	1,092.3	1,118.0	791.2	3,583.7
Big Piney-LaBarge Basinal	$ 6	$ 8	$ (5)	$ (34)	$ (24)	293.7	551.1	564.1	399.2	1,808.0
Big Piney-LaBarge Basinal	$ 0	$ (1)	$ (14)	$ (40)	$ (55)	237.5	445.7	456.1	322.8	1,462.1
Big Piney-LaBarge Basinal	$ (1)	$ (2)	$ (7)	$ (14)	$ (24)	63.0	118.2	120.9	85.6	387.7
Big Piney-LaBarge Basinal	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Big Piney-LaBarge Basinal	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Big Piney-LaBarge Foreland	$ 7	$ 11	$ 2	$ (20)	$ (1)	209.3	392.9	402.1	284.6	1,288.8
Big Piney-LaBarge Foreland	$ 0	$ 0	$ (0)	$ (2)	$ (2)	10.9	20.4	20.9	14.8	67.0
Big Piney-LaBarge Foreland	$ 26	$ 57	$ 43	$ 10	$ 135	329.6	618.6	633.2	448.1	2,029.5
Big Piney-LaBarge Foreland	$ 3	$ 5	$ 3	$ (2)	$ 8	52.7	98.9	101.2	71.6	324.4
Big Piney-LaBarge Foreland	$ 9	$ 15	$ 10	$ (7)	$ 27	168.1	315.4	322.8	228.4	1,034.7
Big Piney-LaBarge Foreland	$ 5	$ 11	$ 6	$ (6)	$ 16	123.1	231.0	236.5	167.3	757.9
Big Piney-LaBarge Foreland	$ 2	$ 4	$ (2)	$ (15)	$ (10)	111.0	208.3	213.2	150.9	683.3
Big Piney-LaBarge Foreland	$ 7	$ 11	$ 1	$ (25)	$ (7)	252.2	473.2	484.4	342.8	1,552.5
Big Piney-LaBarge Foreland	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Big Piney-LaBarge Foreland	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Big Piney-LaBarge Foreland	$ 1	$ 2	$ (7)	$ (24)	$ (28)	151.9	285.0	291.7	206.4	934.9
Big Piney-LaBarge Foreland	$ 3	$ 4	$ (3)	$ (20)	$ (16)	164.6	308.8	316.1	223.7	1,013.2
Big Piney-LaBarge Foreland	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Big Piney-LaBarge Foreland	$ (0)	$ (0)	$ (1)	$ (3)	$ (5)	9.8	18.4	18.9	13.3	60.4
Big Piney-LaBarge Foreland	$ (3)	$ (10)	$ (35)	$ (79)	$ (127)	336.8	632.0	646.9	457.8	2,073.5
Big Piney-LaBarge Foreland	$ (0)	$ (1)	$ (3)	$ (7)	$ (11)	29.5	55.3	56.6	40.0	181.4
Big Piney-LaBarge Foreland	$ (7)	$ (15)	$ (33)	$ (59)	$ (115)	181.2	340.1	348.1	246.3	1,115.6
Big Piney-LaBarge Foreland	$ (3)	$ (7)	$ (18)	$ (35)	$ (64)	132.4	248.5	254.4	180.0	815.4

Area or Field	Economically Recoverable Resources (ERR)--Accessible CO_2 All Drilling									
	NPV					CO_2 ERR				
	10%	20%	30%	40%	Total	10%	20%	30%	40%	Total
	$MM	$MM	$MM	$MM	$MM	Bcf	Bcf	Bcf	Bcf	Bcf
Big Piney-LaBarge Foreland	$ (1)	$ (3)	$ (6)	$ (9)	$ (19)	24.7	46.3	47.4	33.6	152.0
Big Piney-LaBarge Foreland	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Big Piney-LaBarge Foreland	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Big Piney-LaBarge Highland	$ 6	$ 11	$ (0)	$ (26)	$ (9)	222.4	417.4	427.2	302.3	1,369.4
Big Piney-LaBarge Highland	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Big Piney-LaBarge Highland	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Big Piney-LaBarge Highland	$ 13	$ 23	$ 19	$ 2	$ 57	142.6	267.5	273.8	193.8	877.7
Big Piney-LaBarge Highland	$ 2	$ 4	$ 2	$ (3)	$ 5	50.2	94.3	96.5	68.3	309.3
Big Piney-LaBarge Highland	$ 3	$ 5	$ 4	$ (2)	$ 10	60.6	113.7	116.4	82.4	373.1
Big Piney-LaBarge Highland	$ 2	$ 4	$ 1	$ (6)	$ 3	63.5	119.2	122.0	86.3	391.0
Big Piney-LaBarge Highland	$ 1	$ 2	$ (2)	$ (10)	$ (9)	71.0	133.2	136.3	96.5	436.9
Big Piney-LaBarge Highland	$ 2	$ 3	$ (4)	$ (18)	$ (17)	118.6	222.6	227.8	161.2	730.2
Big Piney-LaBarge Highland	$ 0	$ (0)	$ (4)	$ (10)	$ (14)	46.4	87.2	89.2	63.1	286.0
Big Piney-LaBarge Highland	$ 0	$ 0	$ (5)	$ (13)	$ (18)	69.5	130.4	133.5	94.5	427.8
Big Piney-LaBarge Highland	$ 1	$ 1	$ (1)	$ (5)	$ (4)	33.5	62.9	64.4	45.6	206.5
Madden	$ (667)	$ (1,270)	$ (1,448)	$ (1,316)	$ (4,701)	351.4	659.5	675.0	477.7	2,163.5

Exhibit A2-4 CO_2 ERR estimates from CREAM (selective drilling)

Area or Field	Economically Recoverable Resources (ERR)--Accessible CO_2 Selective Drilling									
	NPV					CO_2 ERR				
	10%	20%	30%	40%	Total	10%	20%	30%	40%	Total
	$MM	$MM	$MM	$MM	$MM	Bcf	Bcf	Bcf	Bcf	Bcf
Imperial	$ 0	$ -	$ -	$ -	$ 0	11.3	-	-	-	11.3
Doe Canyon	$ 4	$ 5	$ -	$ -	$ 9	369.3	693.0	-	-	1,062.3
McCallum	$ 14	$ 25	$ 22	$ 6	$ 66	243.3	456.5	467.2	330.7	1,497.7
McElmo Dome	$ 142	$ 254	$ 204	$ 19	$ 619	1,890.5	3,547.8	3,631.2	2,569.8	11,639.2
Oakdale	$ 6	$ 11	$ 10	$ 5	$ 33	82.8	155.3	159.0	112.5	509.6
Sheep Mountain	$ 20	$ 37	$ 39	$ 19	$ 116	220.1	413.1	422.8	299.2	1,355.4
Jackson Dome	$ 116	$ 204	$ 124	$ -	$ 445	2,225.9	4,177.2	4,275.4	-	10,678.4
Kevin Dome	$ 0	$ -	$ -	$ -	$ 0	1,123.5	-	-	-	1,123.5
Kevin Dome	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Bravo Dome	$ 39	$ 70	$ -	$ -	$ 109	1,866.2	3,502.2	-	-	5,368.5
Des Moines	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Estancia	$ 2	$ 3	$ -	$ -	$ 4	77.9	146.1	-	-	223.9
St. Johns/Springerville	$ 53	$ 60	$ 58	$ 5	$ 176	891.4	1,091.9	1,324.2	937.1	4,244.6
Val Verde Basin	$ 1	$ 2	$ 1	$ 0	$ 4	18.9	35.4	36.3	25.7	116.3
Val Verde Basin	$ 16	$ 29	$ 25	$ 12	$ 82	157.9	296.3	303.3	214.6	972.1
Val Verde Basin	$ 1	$ 0	$ -	$ -	$ 1	89.7	168.4	-	-	258.1
Val Verde Basin	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Val Verde Basin	$ 1	$ 1	$ -	$ -	$ 2	98.9	185.7	-	-	284.6
Val Verde Basin	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Val Verde Basin	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Escalante Anticline	$ 1	$ 2	$ -	$ -	$ 3	31.3	58.7	-	-	89.9
Escalante Anticline	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Escalante Anticline	$ 2	$ 3	$ -	$ -	$ 5	45.6	85.5	-	-	131.1
Escalante Anticline	$ 5	$ 9	$ 6	$ -	$ 20	81.3	152.5	156.1	-	389.9
Escalante Anticline	$ 15	$ 27	$ 23	$ 9	$ 74	169.3	317.7	325.2	230.2	1,042.4
Farnham Anticline	$ 0	$ 1	$ 0	$ -	$ 2	8.8	16.5	16.9	-	42.1
Gordon Creek	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Gordon Creek	$ 8	$ 15	$ 9	$ -	$ 32	126.1	236.7	242.3	-	605.1
Lisbon	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Woodside	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Indian Creek	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Big Piney-LaBarge Basinal	$ 27	$ 53	$ 28	$ -	$ 108	679.1	1,274.5	1,304.4	-	3,258.1
Big Piney-LaBarge Basinal	$ 8	$ 14	$ 10	$ -	$ 32	179.4	336.6	344.5	-	860.5
Big Piney-LaBarge Basinal	$ 181	$ 328	$ 320	$ 101	$ 930	2,166.5	4,065.8	4,161.4	2,945.0	13,338.6
Big Piney-LaBarge Basinal	$ 3	$ 6	$ 4	$ -	$ 14	57.5	108.0	110.5	-	276.0
Big Piney-LaBarge Basinal	$ 110	$ 196	$ 145	$ -	$ 452	1,842.8	3,458.3	3,539.6	-	8,840.7
Big Piney-LaBarge Basinal	$ 88	$ 155	$ 103	$ -	$ 347	1,710.6	3,210.1	3,285.6	-	8,206.3
Big Piney-LaBarge Basinal	$ 13	$ 23	$ 16	$ -	$ 53	279.1	523.8	536.1	-	1,339.1
Big Piney-LaBarge Basinal	$ 13	$ 23	$ 18	$ -	$ 54	226.0	424.1	434.0	-	1,084.1
Big Piney-LaBarge Basinal	$ 8	$ 13	$ 3	$ -	$ 24	278.3	522.2	534.5	-	1,335.0
Big Piney-LaBarge Basinal	$ 21	$ 34	$ 7	$ -	$ 62	687.4	1,289.9	1,320.3	-	3,297.6
Big Piney-LaBarge Basinal	$ 10	$ 14	$ -	$ -	$ 24	582.1	1,092.3	-	-	1,674.4
Big Piney-LaBarge Basinal	$ 6	$ 8	$ -	$ -	$ 14	293.7	551.1	-	-	844.8
Big Piney-LaBarge Basinal	$ 0	$ -	$ -	$ -	$ 0	237.5	-	-	-	237.5
Big Piney-LaBarge Basinal	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Big Piney-LaBarge Basinal	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Big Piney-LaBarge Basinal	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Big Piney-LaBarge Foreland	$ 7	$ 11	$ 2	$ -	$ 20	209.3	392.9	402.1	-	1,004.3
Big Piney-LaBarge Foreland	$ 0	$ 0	$ -	$ -	$ 0	10.9	20.4	-	-	31.3
Big Piney-LaBarge Foreland	$ 26	$ 57	$ 43	$ 10	$ 135	329.6	618.6	633.2	448.1	2,029.5
Big Piney-LaBarge Foreland	$ 3	$ 5	$ 3	$ -	$ 11	52.7	98.9	101.2	-	252.8
Big Piney-LaBarge Foreland	$ 9	$ 15	$ 10	$ -	$ 34	168.1	315.4	322.8	-	806.2
Big Piney-LaBarge Foreland	$ 5	$ 11	$ 6	$ -	$ 22	123.1	231.0	236.5	-	590.6
Big Piney-LaBarge Foreland	$ 2	$ 4	$ -	$ -	$ 6	111.0	208.3	-	-	319.3
Big Piney-LaBarge Foreland	$ 7	$ 11	$ 1	$ -	$ 18	252.2	473.2	484.4	-	1,209.7
Big Piney-LaBarge Foreland	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Big Piney-LaBarge Foreland	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Big Piney-LaBarge Foreland	$ 1	$ 2	$ -	$ -	$ 3	151.9	285.0	-	-	436.8
Big Piney-LaBarge Foreland	$ 3	$ 4	$ -	$ -	$ 7	164.6	308.8	-	-	473.4
Big Piney-LaBarge Foreland	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Big Piney-LaBarge Foreland	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Big Piney-LaBarge Foreland	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Big Piney-LaBarge Foreland	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Big Piney-LaBarge Foreland	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Big Piney-LaBarge Foreland	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-

Area or Field	Economically Recoverable Resources (ERR)--Accessible CO_2 Selective Drilling									
	NPV					CO_2 ERR				
	10%	20%	30%	40%	Total	10%	20%	30%	40%	Total
	$MM	$MM	$MM	$MM	$MM	Bcf	Bcf	Bcf	Bcf	Bcf
Big Piney-LaBarge Foreland	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Big Piney-LaBarge Foreland	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Big Piney-LaBarge Foreland	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Big Piney-LaBarge Highland	$ 6	$ 11	$ -	$ -	$ 17	222.4	417.4	-	-	639.8
Big Piney-LaBarge Highland	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Big Piney-LaBarge Highland	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-
Big Piney-LaBarge Highland	$ 13	$ 23	$ 19	$ 2	$ 57	142.6	267.5	273.8	193.8	877.7
Big Piney-LaBarge Highland	$ 2	$ 4	$ 2	$ -	$ 9	50.2	94.3	96.5	-	241.0
Big Piney-LaBarge Highland	$ 3	$ 5	$ 4	$ -	$ 12	60.6	113.7	116.4	-	290.7
Big Piney-LaBarge Highland	$ 2	$ 4	$ 1	$ -	$ 8	63.5	119.2	122.0	-	304.7
Big Piney-LaBarge Highland	$ 1	$ 2	$ -	$ -	$ 3	71.0	133.2	-	-	204.1
Big Piney-LaBarge Highland	$ 2	$ 3	$ -	$ -	$ 5	118.6	222.6	-	-	341.2
Big Piney-LaBarge Highland	$ 0	$ -	$ -	$ -	$ 0	46.4	-	-	-	46.4
Big Piney-LaBarge Highland	$ 0	$ 0	$ -	$ -	$ 0	69.5	130.4	-	-	199.9
Big Piney-LaBarge Highland	$ 1	$ 1	$ -	$ -	$ 2	33.5	62.9	-	-	96.5
Madden	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-

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