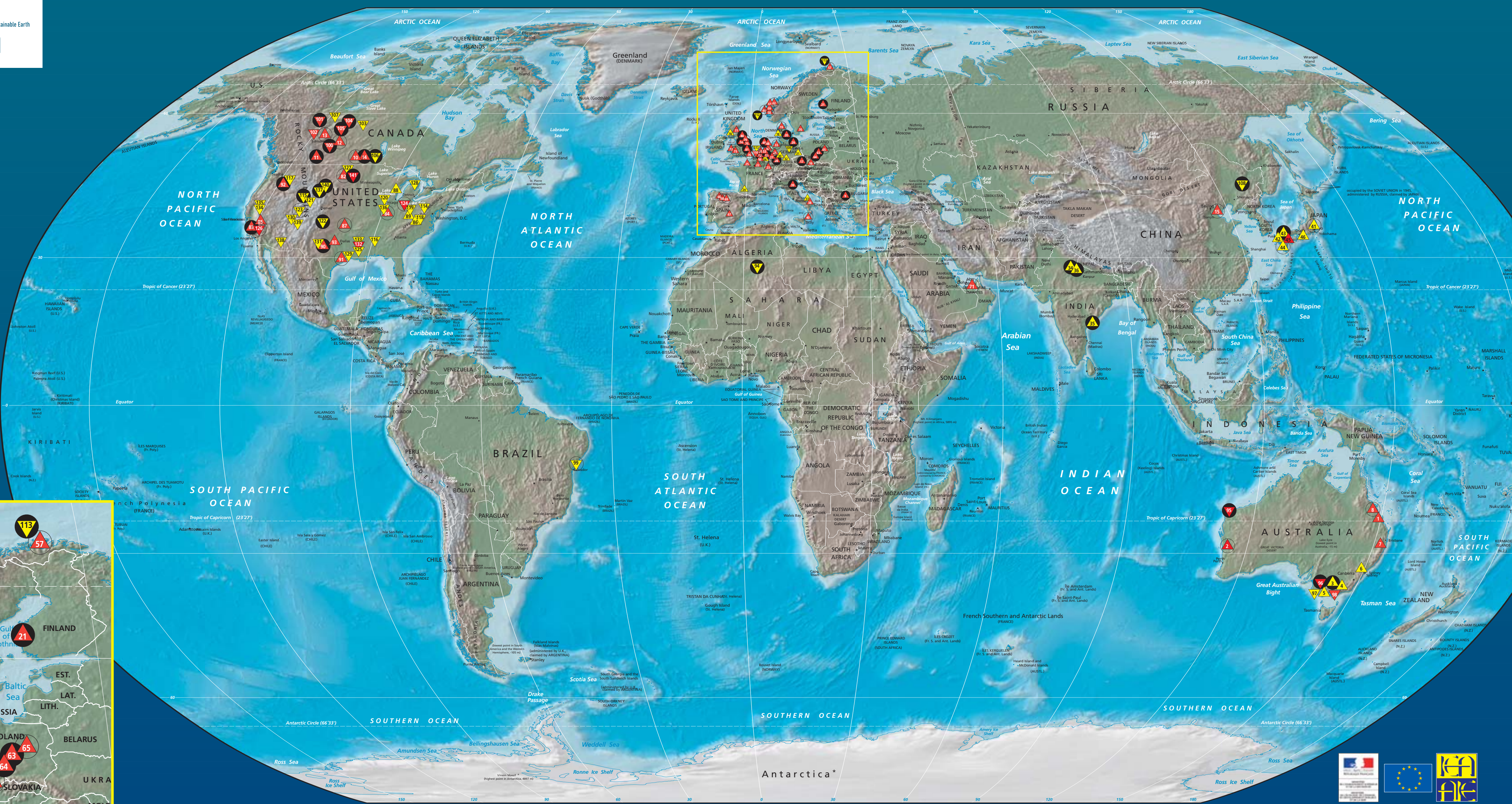
ifp Innovation Energy Environment

ADEME

brgm Geoscience for a sustainable Earth

CO_2 capture and storage projects around the world

Overview of operational and announced projects as of September 2009



R&D / Pilot
Demo
Industrial
Operational projects
Potential projects (planned or announced)

The need to drastically reduce global greenhouse gas emissions, primarily CO_2, is now being progressively recognised at international level.
According to the International Energy Agency (IEA), by 2050, 5 billion tons of CO_2 per year could be avoided through CO_2 Capture and Storage (CCS), representing a 16% contribution to the reduction of global emissions needed to limit climate disruption. CCS must be deployed hand-in-hand with other necessary actions, such as increased energy efficiency and decreased carbon dependency of the energy sector through the use of alternate resources (biomass, solar, wind, geothermal, hydrogen, etc.).
In order to reach the stage of industrial deployment, many barriers must be overcome at various stages of the CCS chain.

In terms of capture, the main challenge is to reduce costs, which currently lie at around 60-80 euros per ton of CO_2 captured.
For transport, adapted infrastructure such as pipeline networks must be set up, and problems resolved concerning the presence of other substances in the CO_2 stream, such as oxygen, nitrogen, NO_x, SO_x.
CO_2 geological storage is undoubtedly the part of the CCS chain that hinges most on gaining public confidence. The efficiency and security of the storage site must not only be controlled in the short term during the few decades of injection and monitoring, but also in the long term (hundreds to thousands of years).
The various segments of the CCS chain are generally studied separately in terms of research at pilot sites that are either capture- or storage-oriented. To date, the technology as a whole has only been deployed at a few pilot sites around the world (Sleipner, Weyburn, In Salah, etc.). The full chain remains to be validated at industrial scale, and this as soon as possible.
The stakes are high: more than 5 billion tons of CO_2 per year could be captured and stored by 2050, which would mean the equivalent of more than 5000 Sleipner-type sites.
The map above presents an overview of existing and forecast CCS projects around the world as of September 2009. The proliferation of announced projects shows that the potential exists for accelerated industrial deployment of the CCS technology. However, as well as the technological and societal barriers mentioned, another challenge is political. Efforts to set up regulations and economic incentives must be continued in order to render these projects viable and stimulate a sufficient amount of others in the short-to-medium term.

△ Capture-oriented and integrated projects

N°	Country	Project Name	Leader(s)	Start-up Date	Amount of CO_2 Captured	Capacity (MW)	Type of Capture Site (and Fuel)	Capture Process	Type of Storage
1	Australia	Callide-A Oxy Fuel	CS Energy	2010	0.03 Mt/y	30	PP (coal)	Oxy	Saline aquifer / Depleted O field
2	Australia	Coolimba	Aviva Corp; AES	2014	n.d.	450	PP (coal)	Oxy	Depleted O&G field
3	Australia	Latrobe Valley (Loy Yang A)	CSIRO; Loy Yang Power	2008	0.001 Mt/y	2200	PP (lignite)	Post	n.d.
4	Australia	Latrobe Valley (Hazelwood H3)	CO2CRC; Int. Power	2009	25-50 t/day	n.d.	PP (lignite)	Post	n.d.
5	Australia	Mulgrave	CO_2CRC; HRL	2009	n.d.	n.d.	PP (coal)	Pre	n.d.
6	Australia	Munmorah PCC (Phase 1)	Delta Electricity; CSIRO	2008	0.004 Mt/y	< 7	PP (coal)	Post	n.d.
7	Australia	Tarong	CSIRO; Tarong Energy	2010	0.003 Mt in total	n.d.	PP (coal)	Post	n.d.
8	Australia	ZeroGen Stage 1	ZeroGen	2012	n.d.	80	PP (coal)	Pre	Saline aquifer
9	Bulgaria	Maritsa	TET	n.d.	3.26 Mt/y	650	PP (lignite)	Pre	Saline aquifer
10	Canada	Boundary Dam	SaskPower	2015	1 Mt/y	100	PP (coal)	Oxy	EOR
11	Canada	Bow City	BCPL; Luscar Ltd.	2014	n.d.	1000	PP (coal)	Post	EOR
12	Canada	Genesee	EPCOR; Enbridge; ARC	n.d.	0.003 Mt/y (1.2 Mt in total)	270	n.d.	Pre	Saline aquifer / EOR
13	Canada	Pioneer	Transalta; Alstom	2012	1 Mt/y	200	n.d. (coal)	Post	Saline aquifer / EOR
14	Canada	Polygen (Belle Plaine)	TransCanada	n.d.	n.d.	500	n.d. (petcoke)	Pre	EOR
15	China	GreenGen Stage 1	CHNG	2011	n.d.	250	PP (coal)	Pre	EOR
16	Czech Republic	Hodonin	CEZ	2015	0.3 Mt/y	105	n.d.	Post	Depleted O&G field
17	Czech Republic	Ledvice	CEZ	2015	0.9 Mt/y	660	PP (n.d.)	Post	Saline aquifer
18	Denmark	CASTOR / CESAR Pilot	IFP: DNO; DONG Energy	2006	1 t/hour	5	PP (coal / fuel)	Post	n.d.
19	Denmark	Kalundborg	DONG Energy	2016	3.4 Mt/y	600	PP (hard coal)	Post	Saline aquifer
20	Denmark	Nordjylland Power Station	Vattenfall	2013	1.8 Mt/y	310	n.d. (coal)	Post	Saline aquifer
21	Finland	Meri Pori	Fortum	2015	3 Mt/y	565	PP (coal)	Oxy	n.d.
22	France	Claye-Souilly CiCO_2	Veolia	2010	0.008 Mt/y	23	Landfill / biogas	Post	Saline aquifer
23	France	Florange	Arcelor Mittal	2010-2016	1.2 Mt/y	n.d.	SP (hard coal / petcoke)	Post	Saline aquifer
24	France	Lacq	Total	2009	0.75 Mt/y	35	PP (oil)	Oxy	Depleted G field
25	France	Le Havre C2A2	EDF	2009	0.005 Mt/y	1	PP (coal)	Post	n.d.
26	Germany	Heyden	E.ON; Cansolv	2012	1% of emissions	7.5	n.d. (coal)	Post	n.d.
27	Germany	Huerth (Goldenbergwerk)	RWE	2015	2.8 Mt/y	450	PP (coal)	Pre	Saline aquifer
28	Germany	Janschwalde	Vattenfall	2015	1.79 Mt/y	500	PP (lignite)	Oxy	Saline aquifer / EGR
29	Germany	Lubmin - Greifswald	DONG Energy	2012	7.6 Mt/y	1500	PP (hard coal)	Post	n.d.
30	Germany	Niederaussem	RWE; Linde; BASF	2009 (P) 2012 (D)	300 kg/h	1 (P); 100 (D)	n.d. (lignite)	Post	n.d.
31	Germany	Schwarze Pumpe	Vattenfall	2008	n.d.	30	PP (coal)	Oxy	EOR
32	Germany	Staudinger Power Station	E.ON; Siemens	2009 (P) 2014 (D)	n.d.	1 (P); 400 (D)	PP (coal)	Post	n.d.
33	Germany	Wilhelmshaven	E.ON	2010	0.57 Mt/y	5,5	PP (hard coal)	n.d.	Saline aquifer
34	India	Aonla & Phulpur	MHI; IFFCO Ltd.	2007	450 t/day	-	CP (n.d.)	Post	Urea prod.
35	India	Kakinada fertilizer complex	MHI; Kansai; NFCL	2009	450 t/day	-	CP (n.d.)	Post	Urea prod.
36	India	Jagdishpur	Indo Gulf Fertilizer Co.; Fluor	1988	55 Mt/y	-	CP (n.d.)	Post	Urea prod.
37	Italy	Brindisi CCS1	ENEL; IFP	2009	1.5 Mt/y	n.d.	PP (coal)	Post	Saline aquifer / Depleted O field
38	Italy	Brindisi CCS2	ENEL	2012	n.d.	35-70	PP (coal)	Oxy	Saline aquifer / Depleted O field
39	Italy	Porto Tolle CCS1	ENEL; ITEA	2012	1.5 Mt/y	660	n.d. (coal)	Post	Saline aquifer / Depleted O field
40	Italy	Saline Joniche	SEI (Rätia Energie and Partners)	2016	3.94 Mt/y	n.d.	PP (hard coal)	Post	Saline aquifer
41	Japan	Chiba	Sumitomo Chemical plants; MHI	1994	55 Mt/y	n.d.	PP / CP (gas)	Post	Food ind.
42	Japan	EAGLE	J-Power; NEDO	2007	150 t/day	n.d.	PP (coal)	Pre	n.d.
43	Japan	Kurosaki	MHI; Kansai	2005	283-330 t/day	n.d.	CP (n.d.)	Post	n.d.
44	Japan	Matsushima	J-Power; MHI	2006	10 t/day	400	PP (coal)	Post	n.d.
45	Japan	Mikawa	Sigma Power Ariake Co.	2010	10 t/day	n.d.	PP (coal)	Post	n.d.
46	Japan	Nanko	MHI; Kansai	1991	2 t/day	n.d.	PP (gas)	Post	n.d.
47	Netherlands	CO_2 Catch up	Nuon	2010	n.d.	n.d.	PP (various)	Pre	n.d.
48	Netherlands	Eemshaven	RWE	2015	0.19 Mt/y	40	PP (coal)	Post	Depleted O&G field
49	Netherlands	Magnum	Nuon	2015	4.14 Mt/y	1200	PP (various)	Pre	Depleted O&G field
50	Netherlands	Pernis	Shell	2011	0.38 Mt/y	127	PP (coal)	Pre	ECBM
51	Netherlands	Rotterdam	Essent; Shell	2016	3.8 Mt/y	1000 (P.P)	PP (hard coal / biomass)	Pre	Depleted O&G field
52	Netherlands	Rotterdam	ENECO; Dong Energy	2011	2 Mt/y	850	PP (gas)	Post	n.d.
53	Netherlands	Rotterdam	CGEN	2014	2.5 Mt/y	450	PP (hard coal / biomass)	Pre	Depleted O&G field
54	Netherlands	Rotterdam CO_2 Catcher-CATO	E.ON Benelux; TNO	2008	5 Mt/y	100	PP (coal / biomass)	n.d.	Depleted O&G field
55	Netherlands	Rotterdam Maasvlakte	GDF SUEZ; E.ON	2015	1 Mt	250	PP (coal)	Post	Depleted G field
56	Netherlands	ZEPP	SEQ N BV; ENECO; TU Delft	2009	0.175 Mt/y	60	PP (gas)	Oxy	EGR
57	Norway	Hammerfest	Hamm. Energi; Sargas; Siemens	2013	0.56 Mt/y	100	PP (gas)	Post	Saline aquifer
58	Norway	Haugesund	Haugaland Kraft	2015	2.25 Mt/y	400	PP (hard coal)	n.d.	n.d.
59	Norway	Husnes	Tinfos; Sor-Norge; Eramet; Sargas	2012	2.5 Mt/y	400	PP (coal)	Post	Saline aquifer
60	Norway	Kårstø	Naturkraft	2012	1.2 Mt/y	420	PP (gas)	Post	Saline aquifer
61	Norway	Mongstad	StatoilHydro	2012	2 Mt/y	40	R (gas)	Post	Saline aquifer
62	Norway	Mongstad	BKK	2014	1.2 Mt/y	450	PP (gas)	Post - Pre	Saline aquifer
63	Poland	Belchatow BOT	PGE Elektrownia B; Alstom	2015	1.7 Mt/y	858 (286 CCS)	PP (lignite)	Post	Saline aquifer
64	Poland	Kedzierzyn	PKE / ZAK	2014	3.4 Mt/y	500	CP (hard coal)	Pre	Saline aquifer
65	Poland	Siekierki	Vattenfall	2016	2.87 Mt/y	480	PP (hard coal)	Post	n.d.
66	Spain	Ciuden CCS Facility	EDP; Endesa	2010	n.d.	20-30	PP (coal)	Oxy	n.d.
67	Spain	ELCOGAS	Endesa; EDF; Iberdrola	2009	0.035 Mt/y	14	PP (various)	Pre	n.d.
68	Spain	OXY-CFB 500	Endesa	2015	2.75 Mt/y	400	PP (various)	Oxy	Saline aquifer
69	Spain	Union Fenosa (La Robla)	Union Fenosa	2016	n.d.	200	n.d. (coal)	Post	Saline aquifer
70	Sweden	Karlshamn	E.ON; Alstom	2014	0.015 Mt/y	5	PP (oil & gas)	Post	n.d.
71	UAE	Masdar	Masdar; BP; Rio Tinto	2014	1.7 Mt/y	420	PP (gas)	Pre	EOR
72	UK	Aberthaw	RWE	2010	n.d.	1	PP (coal)	Post	n.d.
73	UK	Drym	Progressive Energy	n.d.	2.28 Mt/y	450	PP (coal)	Pre	n.d.
74	UK	Ferrybridge	S&SE	2015	0.5 Mt/y	500	PP (coal)	Post	Saline aquifer
75	UK	Hatfield	Powerfuel; UOP	2014	4.75 Mt/y	900	PP (coal)	Pre	EOR
76	UK	Kingsnorth	E.ON UK	2014	2 Mt/y	300	PP (coal)	Post	Depleted G field
77	UK	Longannet	Scot. Power; Alstom; D. Babcock	2014	n.d.	< 50	PP (coal)	Post	Saline aquifer / Coal seams
78	UK	Oxy Coal II Renfrew	S&SE; Doosan Babcock	2009	n.d.	40	n.d. (coal)	Oxy	n.d.
79	UK	Scunthorpe	CORUS	n.d.	n.d.	n.d.	SP (n.d.)	Post	Depleted G field
80	UK	Teeside	Coastal Energy	2013	4.2 Mt/y	800	PP (coal)	Post	EOR
81	UK	Tilbury	RWE	2016	9 Mt/y	1600	PP (coal)	Post	Saline aquifer
82	USA	Antelope Valley	Basin Electric	2012	1 Mt/y	120	PP (coal)	Post	EOR
83	USA	California Project (HECA)	BP; Rio Tinto	2012	4 Mt/y	500	PP (petcoke)	Pre	EOR
84	USA	FutureGen	FutureGen Industrial Alliance	2012	n.d.	275	PP (coal)	Pre	Saline aquifer
85	USA	Kimberlina (ZEPP-1)	WESTCARB; CES	2011	0.25 Mt/y (1 Mt in total)	50	PP (coal / biomass)	Oxy	Saline aquifer
86	USA	Mountaineer	AEP; Alstom	2009	0.1 Mt/y	30	PP (coal)	Post	Saline aquifer
87	USA	Northeastern	AEP; Alstom	2011	1.5 Mt/y	200	PP (coal)	Post	EOR
88	USA	Pleasant Prairie	EPRI; Alstom; WE Energy	2008	n.d..	1,7	PP (coal)	Post	n.d.
89	USA	South Charleston	Alstom; Dow	2009	0.0018 Mt/y	n.d.	n.d. (coal)	Post	n.d.
90	USA	Tenaska Trailblazer Energy Center	Tenaska Inc.	2014	85% of emissions	600	PP (coal)	Post	EOR
91	USA	WA Parish	NRG Energy; Powerspan	2012	1 Mt/y	125	PP (coal)	Post	EOR
92	USA	Wallula Energy R. Center	WRR; Edison Mission Grp	2014	n.d.	914	PP (coal)	Pre	Basalt
93	USA	ZENG Worsham-Steed	CO_2-Global; Falcon Gas	n.d.	870 t/day	70	PP (gas)	Oxy	EOR

PP (Power plant); CP (Chemical plant); SP (Steel plant); R (Refinery); HC (Hard coal); Pre (Pre-combustion); Post (Post-combustion); Oxy (Oxycombustion); EOR (Enhanced Oil Recovery); EGR (Enhanced Gas Recovery); ECBM (Enhanced Coal Bed Methane); n.d. (no data).

▽ Storage-oriented projects

N°	Country	Project Name	Leader(s)	Start-up Date	Amount of CO_2 Injected	Type of Storage
94	Algeria	In Salah	BP; Sonatrach; Statoil	2004	1.2 Mt/y	Depleted O&G field
95	Australia	Gorgon	Chevron; ExxonMobil; Shell	2013	3.3 Mt/y (125 Mt in total)	Saline aquifer
96	Australia	Monash CTL	Shell; Anglo Coal Australia	2015	15 Mt/y	Saline aquifer
97	Australia	Otway Stage 1	CO_2CRC	2008	0.05 Mt/y	Saline aquifer / Depleted G field
98	Australia	Otway Stage 2	CO_2CRC	2010	0.01 Mt in total	Saline aquifer
99	Brasil	Miranga	Petrobras	2009	370 t/d	EOR
100	Canada	Enhance Clive Field	Enhance	n.d.	14 Mt/y	EOR/EGR
101	Canada	Fort Nelson (W. Canada sed. basin)	PCOR Partnership	2011	1 Mt/y	Saline aquifer
102	Canada	Heartland Area Redwater Project (Phase 3)	ARC; ARC Energy Trust	2015	n.d.	n.d.
103	Canada	Pembina	Penn West Energy Trust; ARC	2005	0.05 Mt in total	EOR
104	Canada	Quest CCS project	Shell; Chevron; Marathon Oil Sands	n.d.	1 Mt/y	EOR/EGR
105	Canada	Wabamun Area CO_2 Sequestration Project	U. of Calgary; CCS Research Initiative	n.d.	10 Mt/y (1000 Mt in total)	n.d.
106	Canada	Weyburn	Pan Canadian	2000	2.7 - 3.2 Mt/y	EOR
107	Canada	Zama	PCOR Partnership	2006	0.067 Mt/y	EOR
108	China	Daqing oil field project	CNPC; RITE; Toyota; JGC Corp.	2008	3 Mt/y (150 Mt in total)	EOR
109	Germany	Ketzin	CO_2Sink	2008	0.06 Mt in total	Saline aquifer
110	Netherlands	Barendrecht	Shell	2011	0.38 Mt/y (2 Mt in total)	Depleted G field / Coal seams
111	Netherlands	K12-B (CRUST)	GDF SUEZ	2004	0.02 Mt/y	Depleted G field
112	Norway	Sleipner	StatoilHydro	1996	1 Mt/y (20 Mt in total)	Saline aquifer
113	Norway	Snøhvit	StatoilHydro	2008	0.75 Mt/y	Saline aquifer
114	USA	Appalachian Basin (FirstEnergy's R.E. Burger Plant)	MRCSP	2008	0.003 Mt in total	Saline aquifer
115	USA	BSCSP (Phase 3)	BSCSP	2009	1-3 Mt/y	Saline aquifer
116	USA	Black Warrior Basin	SECARB	2009	0.001 Mt in total	ECBM
117	USA	BSCSP Basalt (Phase 2)	BSCSP	2009	1 kt/y	Basalt
118	USA	Central Appalachian	SECARB	2009	0.001 Mt in total	ECBM
119	USA	East Bend - Cincinnati Arch	MRCSP	2009	0.003 Mt in total	Saline aquifer
120	USA	ECBM Pilot Test	MGSC	2009	0.00075 Mt in total	ECBM
121	USA	Entrada - Green River	SWP	2009	0.1 Mt in total	Saline aquifer
122	USA	Entrada - La Veta	SWP	2008-2012	1 Mt/y (4 Mt in total)	Saline aquifer
123	USA	Farnham Dome	SWP	2008	1 Mt/y (3 Mt in total)	Saline aquifer
124	USA	Greenville TAME Ethanol Plant (Phase 3)	MRCSP	2010-2014	0.28 Mt/y (1 Mt in total)	Saline aquifer
125	USA	Gulf Coast Stacked Storage Project	SECARB	2008	0.05 Mt in total	EOR
126	USA	Kimberlina	WESTCARB	2011	0.25 Mt/y (1 Mt in total)	Saline aquifer
127	USA	Lignite Test (Phase 2)	PCOR Partnership	2008	0.0004 Mt in total	ECBM
128	USA	Michigan Basin	MRCSP	2008-2009	0.06 Mt in total	Saline aquifer
129	USA	Mississippi Test Site	SECARB	2008	0.003 Mt in total	Saline aquifer
130	USA	Paradox EOR	SWP	2009	0.3 Mt in total	EOR
131	USA	Permian Basin - SACROC	SWP	2008	0.35 Mt in total	EOR
132	USA	Phase 3 Anthropogenic Tests	SECARB	2011	0.1 Mt/y	Saline aquifer
133	USA	Phase 3 Early Tests	SECARB	2008	1.5 Mt in total	Saline aquifer
134	USA	Rosetta Resources: Saline	WESTCARB	2008	0.002 Mt in total	Saline aquifer
135	USA	Rosetta Resources: Stacked Gas	WESTCARB	2008	0.002 Mt in total	EGR
136	USA	Saline Formation Test Decatur (Phase 2-3)	MGSC; ADM	2009	1 Mt in total	Saline aquifer
137	USA	Salt Creek	Anadarko	2004	27 Mt in total	EOR
138	USA	Salt River	WESTCARB	2009	0.002 Mt in total	Saline aquifer
139	USA	San Juan Basin	SWP	2008	0.35 Mt in total	ECBM
140	USA	Teapot Dome	US DoE (RMOTC)	2006-2016	2.6 Mt/y	EOR
141	USA	Williston Basin Demonstration	PCOR Partnership	2011	1 Mt/y (5 Mt in total)	EOR

ISBN BRGM n° 978-2-7159-2477-2 - October 2009
Design and production BL Communication