

**West Coast Regional Carbon Sequestration Partnership
(WESTCARB)**

**Assessment of Natural Gas Combined Cycle Plants for Carbon
Dioxide Capture and Storage in Gas-Dominated Electricity Market –
Request for Proposals
RFP# 500-10-502**

PRELIMINARY ASSESSMENT PAPER

TABLE OF CONTENTS

	Page
Summary of Known CO ₂ Capture Technologies.....	1
Summary for Plants Planned or Under Construction	5
Design and Site Characteristics for Operational Plants	8
Generation/Emissions Data for Operational Plants	10
California Map of NGCC Plants and Potential CO ₂ Storage Locations.....	11

SUMMARY OF KNOWN CO₂ CAPTURE TECHNOLOGIES

TECHNOLOGY DEVELOPER	CAPTURE PROCESS	METHOD and/or MEDIUM	LEVEL OF DEVELOPMENT	REMARKS
3H Company	Chemical Absorption	Phase Transition Absorbent – Proprietary solvent	Laboratory-scale testing	Uses a two-part proprietary absorbent that consists of an activated agent dissolved in a solvent with separation of two liquid phases after absorption.
ADA-ES, Inc.	Chemical Adsorption	Solid Sorbents	In development	Uses reversible adsorption of CO ₂ on amine surface-bonded materials such as silica gel.
Air Products	Membrane	Ion Transfer Membranes (ITM) – Non-porous “Perovskite” Ceramic Materials	Pilot-scale testing with larger modules under production	Membranes being developed to reduce parasitic load from cryogenic air separation units used in oxy-combustion process.
Aker Clean	Chemical Absorption	Just Catch – Proprietary Amine	Pilot-scale (slip-stream) testing	Testing two different solvent mixtures.
Alstom	Chemical Absorption	Chilled Ammonia	Pilot-scale (slip-stream) testing	Uses ammonia-CO ₂ -water system to capture CO ₂ from flue gas.
Alstom	Chemical Looping	Limestone-Based Chemical Looping	In development	Separates oxygen from air without using cryogenics or membrane separation. Converts fuel to energy with capture of CO ₂ produced inherent in the process.
Cansolv	Chemical Absorption	DC 103 – Proprietary Amine	Pilot-scale (slip-stream) testing	Can integrate CO ₂ and SO ₂ capture in a single absorber.

TECHNOLOGY DEVELOPER	CAPTURE PROCESS	METHOD and/or MEDIUM	LEVEL OF DEVELOPMENT	REMARKS
Carbozyme, Inc.	Membrane	Enzymatic Carbonic Anhydrase	Laboratory-scale testing	Uses two sets of micro-porous hollow fiber membranes separated by a liquid enzyme to promote absorption and conversion of CO ₂ on the feed side and then reverses the process on the permeate side to enrich CO ₂ in the captured stream.
Clean Energy Systems (CES)	Cryogenic Oxy-Fuel	Conventional Cryogenic Oxygen	Pilot-scale testing planned	Cryogenic air separation to produce oxygen. Advanced concepts are being developed to reduce parasitic load.
CO2/CRC-Australia	Membrane	Hollow Fiber Membrane (HFM)	In development	Uses a membrane to separate feed gas from a liquid solvent. CO ₂ is selectively absorbed into the solvent through the pores in the membrane. Testing a range of membrane materials with a range of solvents.
Codexis	Chemical Absorption	Carbonic Anhydrase Enzyme Catalyzed	Laboratory-scale testing	Uses methyldiethanolamine (MDEA) solution instead of the more common monoethanolamine (MEA) to increase solvent CO ₂ capacity and thermal stability, reduce regeneration heat, and reduce solvent corrosivity.
Eltron Research	Membrane	H ₂ Transport Membrane (HTM)	In development	Uses composite metal alloy or ceramic/metallic mixture to separate hydrogen from syngas. CO ₂ on feed side remains at high pressure and at a concentration suitable for capture.
Fluor-Daniel	Chemical Absorption	Econamine FG Plus SM - Inhibited Amine	In demonstration and/or commercially available	Fluor's Econamine FG Plus SM is an advanced version of Econamine FG SM , a patented commercially available process.

TECHNOLOGY DEVELOPER	CAPTURE PROCESS	METHOD and/or MEDIUM	LEVEL OF DEVELOPMENT	REMARKS
Georgia Tech, et al	Chemical/ Physical Absorption	Ionic Liquid	In development with preliminary results	Uses organic salts with low melting points and negligible vapor pressure to increase CO ₂ loading and reduce heating costs for regeneration.
HTC Purenergy	Chemical Absorption	Proprietary Amine	Pilot-scale (slip-stream) testing	Solvent tailored to customer needs to reduce costs of capture.
Kerr-McGee/ABB Lummus	Chemical Absorption		Developed/applied in small scale in last 30 years.	
Linde AG & Lurgi AG	Physical Absorption	Rectisol Process - Methanol-Based Solvent	Commercially available	
Membrane Technology & Research (MTR)	Membrane	Hollow Fiber Membrane	In development	Requires high CO ₂ partial pressure difference to drive gas diffusion across membrane. Lower post-combustion pressures necessitate membranes with higher permeabilities.
Mitsubishi Heavy Industries (MHI) & Kansai Electric	Chemical Absorption	KM-CDR – Proprietary solvent	In demonstration phase and/or commercially available	Typifies basic chemical absorption process commonly used. Flue gas is cooled and reacted with an amine-based CO ₂ absorbing solution. The CO ₂ -rich solution is then heated to release the CO ₂ for capture and the treated solution reused. Proprietary solvent solution used.
Powerspan	Chemical Absorption	ECO2 Aqueous Ammonia	Pilot-scale (20 tons CO ₂ /day) testing	Scrubber process uses an ammonia-based solution to capture CO ₂ from flue gas.
Praxair	Cryogenic Oxy-Fuel	Conventional Cryogenic Oxygen	In development	Uses low temperature cryogenic distillation to capture CO ₂ from oxy-combustion flue gas.

TECHNOLOGY DEVELOPER	CAPTURE PROCESS	METHOD and/or MEDIUM	LEVEL OF DEVELOPMENT	REMARKS
Praxair	Membrane	Oxygen Transport Membrane	In development	Membranes being developed to reduce parasitic load from cryogenic air separation units used in oxy-combustion process.
RTI International	Membrane	Polymeric Membrane	In development	Requires high CO ₂ partial pressure difference to drive gas diffusion across membrane. Lower post-combustion pressures necessitate membranes with higher permeabilities.
RTI	Physical Adsorption	Warm Gas Cleanup	Pilot-scale (0.5 MWe) testing	Separates CO ₂ from syngas at higher temperatures thereby reducing costs associated with cooling the gas.
Siemens	Chemical Absorption	POSTCAP – Proprietary Amine	Pilot-scale (slip-stream) testing	Uses amino-acid salt formulations.
SRI International	Chemical Adsorption	Solid Sorbents	In development	Uses reversible adsorption of CO ₂ on amine surface-bonded materials such as silica gel.
TDA Research, Inc.	Chemical Adsorption	Solid Sorbents	In development	Uses reversible adsorption of CO ₂ on amine surface-bonded materials such as silica gel.
University of Akron	Chemical Adsorption	Amine-Grafted Zeolite	In development	
UOP	Chemical/Physical Adsorption	Metal Organic Framework	In development with preliminary results	Pillared and inter-layered microporous compounds with open channels sized for gas molecules.
UOP	Physical Absorption	Selexol Process - Glycol-Based Solvent	Commercially available	
Vattenfall/Air Products	Cryogenic Oxy-Fuel	Conventional Cryogenic Oxygen	Pilot plant in operation	Air Products ion transfer membranes are also being developed to help reduce parasitic load.

WESTCARB NGCC-CCS Study
Large California NGCC Plants - Summary for Plants Planned or Under Construction

Configuration Key:
CS = Common Shaft (ST and GT drive a single generator);
IEC= Inlet Evaporative Cooling; IAC = Inlet Air Chiller; SI = Steam Injection; DF = Duct Firing;
1P-1T = single-pressure, once-through HRSG;
Wet CT = Wet Mechanical Draft Cooling Tower; Wet/PA = Wet, Plume-Abated CT;
ACC = Air Cooled Condenser; WS-ACC = Wet Surface Air Cooled Condenser;
ACHE = Air-cooled heat exchanger for condenser cooling;
WSAC = Wet Surface Air Cooler for Lube Oil, etc;
ZLD = Zero Liquid Discharge Wastewater System

Notes:
(1) From pointer location on aerial photos at www.msrmmaps.com
(2) "Est'd Capacity Factor" from licensing documents
(3) Per AFC and Compliance documents, not confirmed with owner.
(4) "CPUC approves plans to convert Tracy power plant to flexible combined cycle facility." PennEnergy.com: August 2, 2010.

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From CEC List of Approved Projects as of 7/30/2010 Plants Approved and/or Under Construction (Arranged By Target Online Date)										Technology	Configuration	No. of F & H GT's	No. of F & H Power Blocks	Combustion Turbine Model	Water/Wastewater ⁽³⁾	NOTES	Plant Latitude ⁽¹⁾	Plant Longitude ⁽¹⁾	Est'd Capacity Factor ⁽²⁾
3	Colusa II Generation Station - PG&E	2006-AFC-9	Colusa	660	4/23/2008	7/28/2008	10/2010 (6/2010)	Under Construction	91	Combined Cycle	2x1, IEC, DF, ACC, WSAC for lube oil, aux boiler 44 MMBtu/hr, gas-fired water bath fuel-gas heater	2	1	GE 7FA	<400 acre-feet per year (AFY) from Tehama-Colusa Canal for process and utility water; sanitary septic system		39.368	-122.270	
5	Lodi Energy Center - NCPA	2008-AFC-10	San Joaquin	296	4/21/2010	7/2010	5/2012 (4/2012)	Under Construction	1	Combined Cycle	1x1 Flex Plant 30, IEC, Wet CT, aux boiler 36.5 MMBtu/hr	1	1	Siemens STG6-5000F	~1651 AFY recycled water from WPCF treated onsite. 1281 avg to 1810 max gpm. 189 gpm max process WW to Underground Injection Well.	Originally 255 MW with GE 7FA Rapid Response with DF	38.0880	-121.3876	70-80%
6	Avenal Energy - Avenal Power Center, LLC	2008-AFC-1	Kings	600	12/16/2009	4/2010	6/2012 (12/2011)	Pre-Construction	0	Combined Cycle	2x1, IAC, DF, ACC, aux boiler 34.7 MMBtu/hr	2	1	GE 7FA	Raw water from City of Avenal/San Luis Canal for Steam cycle makeup; potable for FW & domestic. ZLD. Sanitary septic system.		36.0943	-120.0611	
7	El Segundo Repower - NRG (per pending Amendment)	2000-AFC-14 (See also El Segundo Amend. 00-AFC-14C in Active list)	Los Angeles	560	2/2/2005	11/13/2009	12/2012 (2007)	Under Construction	1	Siemens Rapid Response Combined Cycle (R2C2)	2x1X1 CS, IEC, SI, 1P(-1T?), ACC+ACHes, ZLD,	2	2	Siemens SGT6-5000F	647.3 AFY Reclaim-single-pass-RO + Irrigation Quality; 0.84 AFY Potable; ZLD + Offsite demineralizer regen	Originally 630 MW. Now 1x1 w/ 60 MW single pressure, non-reheat STs; exhaust is condensed in the air cooled back pressure heat exchanger (BPHX); ACHes for auxiliaries	33.9106	-118.4250	up to 60% as amended
8	Victorville Hybrid Gas-Solar - City of Victorville	2007-AFC-1	San Bernardino	563	7/16/2008	?	2013 (8/2010)	Pre-Construction	0	Combined Cycle + Solar Thermal	2x1, IEC, DF+Solar, Wet CT	2	1	GE 7FA	Reclaimed water from Victor Valley Wastewater Reclamation Authority; ZLD process wastewater; city water & sanitary sewer for domestic use	250 acre solar thermal = ~50 MW duct firing	34.6437	-117.3710	
11	Tracy Combined Cycle - GWF Energy LLC	2008-AFC-7	San Joaquin	169+145 =314	3/24/2010	?	Summer 2012 ⁽³⁾ (?)	Approved	0	Combined Cycle (Upgrade from Simple Cycle)	2x1, IEC, DF, ACC, WSAC for lube oil, aux boiler 85 MMBtu/hr			GE 7EA	54.4 AFY; 87 gpm avg: 37 gpm of raw water from BBID/Delta-Mendota Canal and 50 gpm of plant process recycled water. Process wastewater stored/trucked; sanitary septic system	GE 7EA simple cycle units to be upgraded to flexible combined cycle. Key power purchase agreement approved by CPUC in July 2010. Construction start targeted for Q4 2010.	37.7144	-121.4888	
Total Approved In Development or Under Construction				2,679 MW								9 F & H GTs	6 F & H Power Blocks						

From CEC List of Approved Projects as of 7/30/2010 Projects Approved and On Hold																			
	Project Name - Developer	Docket Number	Location County	Capacity (MW)	Date Approved by CEC	Const. Start Date	Target (Original) Online Date	Status	Const. Completed (%)	Technology	Configuration	No. of F & H GT's	No. of F & H Power Blocks	Combustion Turbine Model	Water/Wastewater (3)	NOTES	Plant Latitude ⁽¹⁾	Plant Longitude ⁽¹⁾	Est'd Capacity Factor ⁽²⁾
1	Russell City - Calpine & GE	2001-AFC-07	Alameda	600	10/03/2007	On Hold	On Hold (12/2004)	On Hold	-	Combined Cycle	2x1, DF, Wet CT	2	1	Siemens W501FD	Onsite treatment of secondary effluent for Recycled Water, ZLD; city water for domestic/firewater		37.6380	-122.1364	
3	Morro Bay - L.S. Power	2000-AFC-12	San Luis Obispo	1,200	8/2/2004 Note: Commission decision not finalized pending NPDS permit	On Hold	On Hold	On Hold	-	Combined Cycle	2 -- 2x1, DF, Once-through CW	4	2	GE 7FA	Seawater, subject to flow limits & habitat remediation	Site judged not suitable for ACC; will use once-through seawater and habitat mitigation. Wells for industrial/domestic supply; WW treat on site to outfall or disch to sanitary sewer.	35.3756	-120.8589	
4	Tesla - FPL	2001-AFC-21	Alameda	1,120	6/16/2004	On Hold	On Hold	On Hold (License Expired?)	-	Combined Cycle	2x2x1, IEC, DF, Wet/PA	4	2	GE 7FA	~5100 AFY from CA Aqueduct per Agreement with Rosedale/Rio Bravo District; ZLD + sanitary septic system		37.7410	-121.5720	
6	Pastoria Simple Cycle Addition - Calpine	2005-AFC-1	Kern	160	12/18/2006	On Hold	On Hold (6/2007)	On Hold	-	Simple Cycle	1xSC, IEC (fogging)			GE 7FA	Existing PL from CA Aqueduct; source: Wheeler Ridge Maricopa Water Storage District, Kern Water Bank contacts; existing ZLD	Addition to 2x1 + 1x1 config	34.955	-118.846	
8	East Altamont - Calpine	2001-AFC-04	Alameda	1,100	8/20/2003	8/19/2011 (Deadline extended)	On Hold (7/2005)	On Hold	-	Combined Cycle	3x1, IEC, SI, DF, Wet CT, ZLD, aux boiler	3	1	GE 7FB	~4618 AFY surface water from the Byron Bethany Irrigation District (BBID).	1 MW NG fired emergency gen; diesel fire pump	37.8056	-121.5755	
11	Blythe II - Caithness	2002-AFC-01, 2009-10-26_Amendment.pdf	Riverside	569-520	12/14/2005	On Hold	On Hold	On Hold	-	Siemens Flex Plant 30 Rapid Start Combined Cycle	2x1, IAC, DF, Wet CT, Aux Boiler 60 MMBtu/hr	2	1	Siemens SGT6-5000F	3,300 AFY degraded groundwater from 2x3000 gpm well, ZLD with standby evap pond; sanitary septic system; voluntary conservation offset.	CO2e = 1,870,000 – 1,930,000 metric tons/year; 538 MW max output	33.6139	-114.6864	
Total Approved -- On Hold				4,700 MW								15 F & H GTs	7 F & H Power Blocks						

From CEC List of Projects in Review as of 7/30/2010 (Arranged in Alphabetical Order)										Technology	Configuration	No. of F & H GT's	No. of F & H Power Blocks	Combustion Turbine Model	Water/Wastewater (3)	NOTES	Plant Latitude ⁽¹⁾	Plant Longitude ⁽¹⁾	Est'd Capacity Factor ⁽²⁾
6	Carlsbad - NRG	2007-AFC-6	San Diego	558 gross 540 net	9/14/2007	Q1-2 2010 in Nov'09 FSA	Summer 2012 in Nov'09 FSA (7/2010)		-	flex Plant 10 Combined Cycle	2x1, IEC, SI, ACC	2	1	Siemens SGT6-PAC5000F	Reclaimed or desal for industrial water uses; potable from Carlsbad Municipal Water District		33.1431	-117.3324	
8	CPV Vaca-Station - CPV Vacaville LLC	2008-AFC-11	Solano	660	11/18/2008		?		-	Combined Cycle	2x1, IEC, SI, DF, Wet CT, Aux Boiler	2	1	GE 7FA or Siemens SGT6-PAC5000F	Reclaimed (Secondary) WW, treat on site, up to 6.3 mgd; Tertiary backwash to WWTF; ZLD for balance (+sanitary sewer)		38.3390	-121.8970	
9	El Segundo Power Redevelopment Projects, Dry Cooling Amendment - NRG	2000-AFC-14C	Los Angeles	See 00-AFC-14	6/22/2007		?(6/10)		-	SEE ABOVE under licensed projects				SEE ABOVE under licensed projects			33.9106	-118.4250	
11	Hybrid Gas-Solar - City of Palmdale (555 MW gas + <u>62 MW solar</u>)	2008-AFC-9	Los Angeles	617	8/4/2008		2013		-	Combined Cycle + Solar Thermal	2x1, IEC, DF+Solar, Wet CT, ZLD	2	1	GE 7FA	Tertiary WW for cooling from City of Palmdale w Backup from Lancaster via regional backbone, ZLD (+Sanitary Sewer)	250 Acre Solar Field	34.6465	-118.1042	
14	Marsh Landing Generating Station - Marsh Landing LLC	2008-AFC-3	Contra Costa	990 760	5/30/2008		?		-	Now Simple Cycle (originally CC + SC)	Four Simple Cycle peakers with IEC plus two NG fired preheaters (dew point heaters)	(four "F" in SC)		Siemens SGT6-5000F	On-site degraded groundwater	Originally filed as two Flex Plant 10 CC units (550 MW) at 40-50% capac factor plus two simple cycle peakers at <10% est capac factor; The FP10 units can operate at partial load, with the CTGs operating down to minimum load (60 percent) while keeping the STG on-line or off-line.	38.0186	-121.7662	Up to 20%
15	Oakley Generating Station (formerly Contra Costa)	2009-AFC-4	Contra Costa	624	6/30/2009		?		-	Combined Cycle	2x1, IEC, ACC, ACHE+WSAC for aux-cooling loop, Aux boiler 34 kpph	2	1	GE 7FA with metallurgical upgrade for 213 MW nominal	Potable water (95 gpm average, 369 gpm peak, 240 AFY average annual) for process/domestic; discharge to Ironhouse Sanitary District sewer		38.0112	-121.7481	60-80%
-	San Gabriel - Reliant	2007-AFC-2	San Bernardino	[656]	4/13/2007		-	Suspended During Review	-										
25	Willow Pass Generating Station - Mirant	2008-AFC-6	Contra Costa	550	6/30/2008		7/2012		-	Flex Plant 10 Combined Cycle	2--1x1, IEC, DF, ACC, Fuel Gas Preheater	2	1	Siemens SGT6-5000F	~781 AFY total consumption; Delta Diablo Sanitation District recycled water/wastewater return. City of Pittsburg potable water. Reclaimed (Secondary) WW, treat on site, up to 6.3 mgd; Tertiary backwash to WWTF; ZLD for balance (+sanitary sewer)		38.0415	-121.8935	40-50%
Total in Review by CEC				3,201 MW								10 F & H GTs	5 F & H Power Blocks						

Large California NGCC Plants
Design and Site Characteristics for Operational Plants

Configuration Key:
CS = Common Shaft (ST and GT drive a single generator);
IEC= Inlet Evaporative Cooling; IAC = Inlet Air Chiller; SI = Steam Injection; DF = Duct Firing;
1P-1T = single-pressure, once-through HRSG;
Wet CT = Wet Mechanical Draft Cooling Tower; Wet/PA = Wet, Plume-Abated CT;
ACC = Air Cooled Condenser; WS-ACC = Wet Surface Air Cooled Condenser;
ACHE = Air-cooled heat exchanger for condenser cooling;
WSAC = Wet Surface Air Cooler for Lube Oil, etc;
ZLD = Zero Liquid Discharge Wastewater System

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Plant Data from CEC Database of California Power Plants (September 2009), except where italicized					BK _i Compilation and Assessment (from Cursory Review of Multiple Sources)								Capacity Factor	Available Space and Neighboring Land Use ⁽²⁾	Water / Wastewater ⁽³⁾
ID	PLANTNAME (ALIAS)	COUNTY	YEAR ONLINE	ONLINE _MW	<i>Plant Latitude⁽¹⁾</i>	<i>Plant Longitude⁽¹⁾</i>	Configuration	No. of F & H GT's	No. of F & H Power Blocks	Gas Turbine Model	Miscellaneous Notes				
G0843	BLYTHE ENERGY POWER PLANT PROJECT	RIVERSIDE	2003	520.0	33.614	-114.686	2x1, IAC(?), DF, Wet CT	2	1	Siemens V84.3a		CF low in 2005, 2008, 2009. Blythe 2 (comparable power block) on hold.	Large site in desert/cropland location. There appears to be ample space for capture & compression for Blythe 1 and Blythe 2. Location less than 1 mile from new airport and freeway may require plume abatement or dry cooling.	3,000 acre-feet per year (AFY) degraded groundwater; ~2000 gpm from 3 wells, ZLD with evap pond; sanitary septic system; voluntary conservation offset. May need dry cooling to serve CCS if proposed Blythe 2 is installed.	
G0161	CROCKETT COGEN	CONTRA COSTA	1995	247.0	38.056	-122.218	1x1-CS, ACC (Cogen steam to C&H Sugar Refinery)	1	1	GE 7FA	Potential location for CO ₂ -EOR?	CF <50%; cogen tied to sugar refinery operation.	Very tight site (ACC is above HRSG & CT/generator/ST train); close to residential area.		
G0783	DELTA ENERGY CENTER (DELTA LLC, DELTA-CALPINE)	CONTRA COSTA	2002	860.2	38.017	-121.844	3x1, SI, DF, Wet CT, 2 aux boilers	3	1	Siemens-Westinghouse W501F		CF ~65% avg for 2005, 2008, 2009.	Small site - 3x1 power block and cooling tower on 20 acres. Google satellite photo shows large open space to south, west, and northeast of site.	Raw water from Contra Costa Canal for demin. Reclaimed water from Delta Diablo San District for cooling. WW to DDSD. Future water availability for capture system cooling may be an issue.	
G0799	ELK HILLS (ELK HILLS GENERATING PROJECT)	KERN	2003	567.0	35.280	-119.311	2x1, IEC, SI, DF, Wet CT	2	1	GE 7FA	Potential location for CO ₂ -EOR?	CF ~66-71% for 2005, 2008, 2009.	Does not appear to be laid out well for capture within fence-line of current 12-acre site. Space may be available on adjoining oil field property.		
G0950	GATEWAY GENERATING STATION (CONTRA COSTA UNIT 8 REPOWER, CONTRA COSTA REPOWER)	CONTRA COSTA	2009	530.0	38.018	-121.761	2x1, IAC, DF, ACC, WSAC + fin-fan for aux cooling loop	2	1	GE 7FA (Dual Fuel?)	Aug. 1, 2007 amendment changed cooling to ACC+WSAC+FinFan; eliminated STIG; added IAC	CF >50% in startup year 2009.	Adequate space for capture equipment may be available west of Gateway GS stacks, on adjoining Mirant property that is currently designated for laydown and trailers for construction of Marsh Landing GS (see aerial & plan in Marsh Landing AFC). Compressors and dry cooling for CO2 capture may fit in open space south of current ACC.	Potable water from Diablo Water District; discharge to Ironhouse Sanitary District.	
G0249	HAYNES (HAYNES #3-#4 (eGRID Blr/Gen 9-10))		2005	575.0	33.764	-118.094	2x1, DF,	2	1	GE 7FA Dual-Fuel		CF >60% avg for 2008-09	Google satellite photos shows space near stack that may be suitable for absorbers, plus apparent adequate space for balance of CCS equipment to the north. Space availability may depend on needs for once-through cooling phase-out. Residential areas ~1/4 mile east and ~3/4 mile west.	New California rules appear to require phaseout of once-through cooling now used for NGCC unit and 5 fired-boiler steam units. Change to cooling towers or ACC?	
G0778	HIGH DESERT POWER PLANT PROJECT (HIGH DESERT - CONSTELLATION)	SAN BERNARDINO	2003	854.9	34.595	-117.365	3x1, DF, Wet CT	3	1	Siemens-Westinghouse W501FD2		CF ~60% avg for 2008-09; ~49% in 2005	Aerial photo (2009 compliance submittals) appears to indicate adequate space on adjoining land for CCS equipment. Space adjacent to stacks is marginal - moderately long ducts may be required for flue gas to absorbers. Although current facility uses a wet CT, proximity of airport and limited water supply may require air cooling for future CCS.	~3200 AFY from State Water Project (SWP); backup with water bank wells; conversion to Victor Valley WRA reclaimed tertiary water (up to 1000 AFY) began in 2009? If successful, target for full reclaim supply is 2012. ZLD. Water availability for CCS may be limited.	
G0868	INLAND EMPIRE ENERGY CENTER	RIVERSIDE	2009 / 2010	800.0	33.742	-117.171	2 -- 1x1-CS, IAC, Fuel moisturizing, Wet CT, aux boiler 152 MMBtu/hr/120 kpph	2	2	GE 107H	Project originally approved with 7FA GTs with STIG & DF; revised to 7H GTs without augmentation. Unit 2 damaged during commissioning in Aug. 2009; online in April 2010.	CF ~30% for one block in startup year 2009.	Project occupies 35 acres of 45.8-acre site; fenced area ~28 acres. Surrounding land uses appear to leave room for expansion if needed to accommodate CCS. Space adjacent to stacks is marginal - moderately long ducts may be required for flue gas to absorbers.	Recycled and raw water from Eastern Municipal Water District supplemented with raw water from Metropolitan WD; 95% recycled increasing to 100% with raw water backup. 3034-4018 gpm. 4182 AFY avg, 4842 AFY max. Wastewater to EMWD.	
G0781	LA PALOMA GENERATING PROJECT (LA PALOMA -PG&E NATL. UNITS 1, 2, 3, 4)	KERN	2003	1200.0	35.296	-119.592	4 -- 1x1-CS, SI, 4x Diesel Emerg Gen	4	4	Alstom (ABB) GT-24	Aug. 1, 2007 amendment approved change of WW disposal to deep wells with ZLD backup (due to ZLD performance issues).	CF ~60% avg for 2008-09; ~41% in 2005	Undeveloped land surrounds the site. Public road located just south of stacks (possible location for CO ₂ absorbers if road can be moved).	Raw and potable water from the West Kern Water District (SWP water from the California Aqueduct). Primary WW disposal is by injection wells, backup by ZLD system. ZLD boiler limit is 148.8 MMBtu/day.	
G0780	LOS MEDANOS ENERGY CENTER (PITTSBURG DISTRICT ENERGY FACILITY)	CONTRA COSTA	2001	594.0	38.030	-121.871	2x1, DF, Wet CT (Cogen steam to USS Posco)	2	1	GE 7FA		CF ~59-65% for 2005, 2008, 2009; fractional cogen supply to USS-Posco.	Small site - 2x1 power block and cooling tower on 12 acres with stacks near middle of site. Google satellite photo shows open space east, west, and southwest of site with adequate size for CCS.	Disinfected tertiary treated recycled water from Delta Diablo Sanitation District; wastewater return to DDSD.	
G0329	MAGNOLIA (MAGNOLIA POWER PLANT, MAGNOLIA MODERNIZATION PROJECT)	LOS ANGELES	2005	309.7	34.179	-118.315	1x1, IEC, SI, DF, Wet CT	1	1	GE 7FA		CF ~58-60% for 2008-09	Small urban industrial site without significant available space; nearby commercial/industrial neighbors and residences within ~0.25 mile.	Potable water from City of Burbank; reclaimed water from the Burbank Water Reclamation Plant; wells and SWP for backup; ZLD process water treatment; industrial to BWRP; sanitary sewer; potential for future supply for CCS cooling not clear from BWP 2007 Recycled Water Master Plan.	
G0794	METCALF ENERGY CENTER	SANTA CLARA	2005	565.8	37.217	-121.744	2x1, IEC, SI, DF, Wet/PA CT	2	1	Siemens-Westinghouse W501FD2		CF ~36% in startup year 2005; ~64% in 2008; ~56% in 2009.	Site layout is compact - probably would require long duct to absorber. Google satellite photo gives appearance of ample space just south of site - currently used for laydown area, crops, and tree-screen. Proposed business park and "nearby" residential development presented significant opposition during licensing.	Recycled water from South Bay Water Recycling (SBWR) Program; potable and backup from San Jose Muni Water System or wells. Process and sanitary wastewater to city sewer.	
G0372	MOSS LANDING (MOSS LANDING UNIT 1, 2, 6, 7)	MONTEREY	2002	1020.0	36.804	-121.778	2 -- 2x1, once-through	4	2	GE 7FA	Units 6 & 7 are old steam boilers	CF appears to be ~54% in 2008; ~49% in 2009. Low value for 2005 may reflect calculation including old steam units.	Arrangement of 4 stacks along central pipeway may require moderately long ducts to absorbers. Ample space appears to be available where old tank farm was removed during CC repower.	New California rules appear to require phaseout of once-through cooling now used for NGCC units and 2 fired-boiler steam units. Change to cooling towers or ACC?	
G0795	MOUNTAINVIEW POWER PROJECT (MOUNTAINVIEW POWER PLANT)	SAN BERNARDINO	2005	1054.0	34.084	-117.241	2 -- 2x1, IEC, DF, Wet CT	4	2	GE 7FA	Potential upgrade to IAC mentioned in <i>Combined Cycle Journal</i> (Q4 2006). Implemented?	CF ~73% in 2008; ~62% in 2009.	Plant appears to have plot space (or equipment easily moved) for absorbers to west & south of stacks. Regenerators, compressors, new cooling could be near cooling towers east of power block. Little or no space appears to be available outside of property due to commercial/industrial development to east and south; commercial & residential areas to west and southwest.	Contaminated groundwater is treated for use as plant cooling water and supplemented by reclaimed wastewater from Redlands Wastewater Treatment Plant. (Pumping of this groundwater should help prevent the flow of contaminants to high-quality groundwater.) "Near-ZLD" with blowdown to Santa Ana Regional Intercept.	

Plant Data from CEC Database of California Power Plants (September 2009), except where italicized					BK _i Compilation and Assessment (from Cursory Review of Multiple Sources)									
ID	PLANTNAME (ALIAS)	COUNTY	YEAR ONLINE	ONLINE _MW	<i>Plant Latitude⁽¹⁾</i>	<i>Plant Longitude⁽¹⁾</i>	Configuration	No. of F & H GT's	No. of F & H Power Blocks	Gas Turbine Model	Miscellaneous Notes	Capacity Factor	Available Space and Neighboring Land Use ⁽²⁾	Water / Wastewater ⁽³⁾
	<i>OTAY MESA GENERATING PROJECT</i>	<i>SAN DIEGO</i>	<i>2009</i>	<i>600.0</i>	<i>32.577</i>	<i>-116.913</i>	2x1, IEC, DF, ACC (+WSAC?), aux boiler 87 MMBtu/hr	2	1	GE 7FA	2003 amendment deleted STIG; added aux boiler.	~15% CF in startup year 2009.	Site is ~15 acres within ~46 acre property. Surrounding land use appears to be fallow ag land. ~1 mile to correctional facility & some businesses. Preliminary drawings appear to indicate room for absorbers near stacks; other capture facilities could fit elsewhere. Amended drawings not available on CEC website. Google satellite pictures too early in construction to judge.	Potable water from Otay Water District; recycled water when available. Wastewater to existing sewerage in Johnson Canyon. Addition of CCS would require dry cooling.
G0861	PALOMAR ESCONDIDO (PALOMAR POWER (SEMPRA ENERGY RESOURCES))	SAN DIEGO	2006	559.0	33.122	-117.118	2x1, IAC, DF, Wet/PA CT	2	1	GE 7FA	Upgrade to IAC approved in 2007 (in place?). <i>Combined Cycle Journal</i> (Q4 2006) -- 2007 Pacesetter Plant. Petition 5/18/2010 to add gas-fired emergency gen.	CF ~73% in 2008; ~67% in 2009.	Small site in noise- and emissions-sensitive suburban setting. Commercial due east; residential 1/4 mile west. Open space due west at time of Google satellite photo appears adequate for absorbers with ~300 feet of duct from stack; open space due south would require ~500 ft of duct to absorbers. Low-noise cooling and compression could present a challenge.	Tertiary treated recycled water from City of Escondido Hale Avenue Resource Recovery Facility (HARRF). Brine cooling tower blowdown returned to HARRF. Adequacy for wet cooling for future CCS not clear. Backup with raw water authorized post-certification.
G0797	PASTORIA ENERGY FACILITY (PASTORIA ENERGY FACILITY PHASE 1 & 2, PASTORIA UNIT 1 - UNIT 2)	KERN	2005	760.0	34.956	-118.844	2x1 + 1x1, IEC or IAC, SI, DF, Wet CT	3	2	GE 7FA	Potential location for CO ₂ -EOR?	CF~39% in 2005; ~74% in 2008; ~75% in 2009.	Space for absorbers near stacks appears marginal. Plentiful space now used for grazing is available outside plant fence. Nearest land uses are ag and quarry.	Existing water supply from SWP CA aqueduct (purchase of WRMWSD excess water or banked water from Kern Water Bank); ZLD and sanitary septic system. Water for CCS may be available.
G0889	SMUD CONSUMNES RIVER PHASE 1 (SMUD CONSUMNES POWER PLANT)	SACRAMENT O	2006	500.0	38.338	-121.122	2x1, IEC (fogging), Wet CT	2	1	GE 7FA	Feb. 2009 amendment added filter & rev'd ZLD system to accommodate lower water qual. due to new Freeport Reg'l Water Authority outake to FSC from Sacramento River.	CF ~88% in 2008; ~79% in 2009.	Appears to have room near stacks for absorbers and agricultural space outside fence for balance of CCS.	Phase I uses 2.5 mgd avg, 3.5 mgd peak; water requirements would double with proposed Phase 2. ~2,663 AFY from Sacramento River & American River via Folsom South Canal (U.S. BOR contract renewal by 2012; CVP Impr. Act gives fish & wildlife equal rights to water); ZLD (original AFC--4,000 AFY w/o ZLD).
G0784	SUNRISE POWER PROJECT	KERN	2001-SC 2003-CC	572.0	35.210	-119.585	2x1, IEC, DF, Wet CT	2	1	GE 7FA	Potential location for CO ₂ -EOR?	CF ~72% in 2008-09.	Google satellite photos shows space near stacks that may be suitable for absorbers. Site is surrounded by desert land heavily impacted by oil field operations -- land for balance of CCS equipment appears to be available in space between wells and piping.	~3,900 AFY consumption; water from West Kern Water District well fields; wastewater disposal system to TCI Station 2-22 to recycle for EOR plus six deep injection wells for wastewater disposal.
G0779	SUTTER POWER PROJECT (SUTTER-CALPINE, SUTTER EC)	SUTTER	2001	551.8	39.053	-121.694	2x1, IEC, DF, ACC	2	1	Siemens-Westinghous e W501F		2 years w CF <50%; avg >50%.	Google satellite photos shows space near stack that may be suitable for absorbers. Unused plant property appears adequate for balance of CCS equipment.	>140 GPM annual average water consumption (60,000 gpd -- 318,000 gpd; 67-356 AFY). Process/potable water from onsite well; onsite treatment of process wastewater and sanitary sewage treatment; water recycle; ZLD.
G0648	VALLEY (VALLEY REPOWER)	LOS ANGELES	2004	533.0	34.248	-118.390	2x1	2	1	GE 7FA Dual-Fuel		CF ~55% in 2008-09.	Google satellite photos shows space near stack that may be suitable for absorbers. Use of other plant property for balance of CCS equipment may depend on plans for old boilers and cooling towers.	
G0900	WALNUT ENERGY CENTER (TID COMBINED CYCLE, WALNUT ENERGY CENTER, WEC)	STANISLAUS	2006	275 (300.6?)	37.555	-120.989	2x1, IEC, Wet CT			GE 7EA	Note - GE 7EA; <i>Combined Cycle Journal</i> Pacesetter Plant (Q4 2006)	CF ~60% in 2008; ~58% in 2009.	Adjoins farm/grazing land. Appears to have space for CCS.	Up to 1800 AFY tertiary treated wastewater from City of Turlock Regional Wastewater Treatment Plant (after May 2006; potable water for "bridge supply"); potable supply for domestic & firewater); ZLD process water treatment; sanitary septic system/leachfield.

Notes: (1) From EPA e-GRID or pointer location on aerial photos at www.msrmaps.com

(2) Not verified with owner/operator or city/county planning department.

(3) Not verified with owner/operator or permitting/enforcement agency.

49 F- & H- Class GTs	28 F- & H- Class Power Blocks
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WESTCARB NGCC-CCS Study
Large California NGCC Plants
Generation/Emissions Data for Operational Plants

Configuration Key:
CS = Common Shaft (ST and GT drive a single generator);
IEC= Inlet Evaporative Cooling; IAC = Inlet Air Chiller; SI = Steam Injection; DF = Duct Firing;
1P-1T = single-pressure, once-through HRSG;
Wet CT = Wet Mechanical Draft Cooling Tower; Wet/PA = Wet, Plume-Abated CT;
ACC = Air Cooled Condenser; WS-ACC = Wet Surface Air Cooled Condenser;
ACHE = Air-cooled heat exchanger for condenser cooling;
WSAC = Wet Surface Air Cooler for Lube Oil, etc;
ZLD = Zero Liquid Discharge Wastewater System

Plant Data from CEC Database of California Power Plants (September 2009), except where italicized					Operating Data from 2009 December EIA-923 Monthly Time Series File (italicized values calculated by BKI) ⁽¹⁾					Operating Data from 2008 December EIA-923 Monthly Time Series File (italicized values calculated by BKI) ⁽¹⁾					Operating Data from EPA eGRID2007 Version 1.1 Plant File (Year 2005 Data)								
ID	PLANTNAME (ALIAS)	COUNTY	YEAR ONLINE	ONLINE MW	Total Fuel Consumption MMBtu	Total Net Generation (MWh)	Net Heat Rate (Btu/kWh)	Est'd CO ₂ Emissions (Tons)	Est'd Capacity Factor	Total Fuel Consumption MMBtu	Total Net Generation (MWh)	Net Heat Rate (Btu/kWh)	Est'd CO ₂ Emissions (Tons)	Est'd Capacity Factor	Plant capacity factor	Plant nameplate capacity (MW- gross)	Plant annual heat input (MMBtu)	Plant <u>unadjusted</u> annual heat input (MMBtu)	Plant annual net generation (MWh)	Plant annual CO ₂ emissions (tons) (adjusted) ⁽⁶⁾	Plant <u>unadjusted</u> annual CO ₂ emissions (tons)	Annual CO ₂ emission rate (lb/MWh output) (adjusted) ⁽⁶⁾	Plant nominal heat rate (Btu/kWh) (adjusted) ⁽⁶⁾
G0843	BLYTHE ENERGY POWER PLANT PROJECT	RIVERSIDE	2003	520.0	10,176,154	1,406,429	7,235	604,718	0.309	10,355,505	1,383,869	7,483	615,412	0.304	0.176	591.0	6,684,426	6,684,426	911,018	397,245	397,245	872	7337
G0161	CROCKETT COGEN	CONTRA COSTA	1995	247.0	8,040,367	682,429	11,782	477,799	0.315	9,309,402	888,311	10,480	553,211	0.411	0.429	247.4	8,213,544	10,056,380	929,544.2	480,364	588,141	1034	8836
G0783	DELTA ENERGY CENTER (DELTA LLC, DELTA-CALPINE)	CONTRA COSTA	2002	860.2	36,882,025	5,013,277	7,357	2,191,714	0.665	35,521,394	4,825,914	7,361	2,110,859	0.640	0.648	943.5	37,988,940	37,988,940	5,359,470	2,257,632	2,257,632	842	7088
G0799	ELK HILLS (ELK HILLS GENERATING PROJECT)	KERN	2003	567.0	24,205,962	3,452,893	7,010	1,438,439	0.695	24,926,324	3,551,893	7,018	1,481,247	0.715	0.658	623.0	24,680,270	24,680,270	3,590,648	1,466,706	1,466,706	817	6873
G0950	GATEWAY GENERATING STATION (CONTRA COSTA UNIT 8 REPOWER, CONTRA COSTA REPOWER)	CONTRA COSTA	2009	530.0	18,096,256	2,490,206	7,267	1,075,370	0.536														
G0249	HAYNES (HAYNES #3-#4 (eGRID Blr/Gen 9-10))		2005	575.0	21,138,712	2,953,831	7,156	1,256,168	0.586	27,257,511	3,277,428	8,317	1,619,778	0.651			16,649,400	31,555,920		989,294 ⁽²⁾	1,875,177		
G0778	HIGH DESERT POWER PLANT PROJECT (HIGH DESERT - CONSTELLATION)	SAN BERNARDINO	2003	854.9	29,877,167	4,265,280	7,005	1,775,451	0.570	33,516,478	4,704,901	7,124	1,991,717	0.628	0.490	852.0	26,463,888	26,463,888	3,656,116	1,572,707	1,572,707	860	7238
G0868	INLAND EMPIRE ENERGY CENTER	RIVERSIDE	2009 / 2010	800.0	7,613,603	1,110,335	6,857	452,438	0.158														
G0781	LA PALOMA GENERATING PROJECT (LA PALOMA -PG&E NATL. UNITS 1, 2, 3, 4)	KERN	2003	1200.0	44,964,443	6,339,567	7,093	2,672,012	0.603	45,144,224	6,185,233	7,299	2,682,696	0.588	0.421	1,200.0	36,424,861	36,424,861	4,427,010	2,164,683	2,164,683	978	8228
G0780	LOS MEDANOS ENERGY CENTER (PITTSBURG DISTRICT ENERGY FACILITY)	CONTRA COSTA	2001	594.0	24,422,613	3,358,184	7,273	1,451,314	0.645	22,591,317	3,064,966	7,371	1,342,489	0.589	0.605	678.3	26,035,686	26,670,505	3,594,588	1,547,266	1,584,993	861	7243
G0329	MAGNOLIA (MAGNOLIA POWER PLANT, MAGNOLIA MODERNIZATION PROJECT)	LOS ANGELES	2005	309.7	11,665,710	1,623,642	7,185	693,235	0.598	11,387,145	1,571,797	7,245	676,681	0.579	0.016 ⁽³⁾	387.6	2,867,301	2,867,301	52,918	170,418	170,418	6441	54189
G0794	METCALF ENERGY CENTER	SANTA CLARA	2005	565.8	19,171,009	2,778,697	6,899	1,139,237	0.561	21,624,466	3,152,211	6,860	1,285,034	0.636	0.363	635.0	15,880,602	15,880,602	2,020,895	943,761	943,761	934	7858
G0372	MOSS LANDING (MOSS LANDING UNIT 1, 2, 6, 7)	MONTEREY	2002	1020.0	34485771 ⁽⁵⁾	4,386,230 ⁽⁵⁾	7,862	2,049,317 ⁽⁵⁾	0.491	35,184,497 ⁽⁵⁾	4,846,562 ⁽⁵⁾	7,260 ⁽⁵⁾	2,090,839 ⁽⁵⁾	0.542 ⁽⁵⁾	0.217 ⁽²⁾	2802 ⁽²⁾	39,993,240	39,993,240	5,331,135 ⁽²⁾	2,376,736 ⁽²⁾	2,376,736	892 ⁽²⁾	7502 ⁽²⁾
G0795	MOUNTAINVIEW POWER PROJECT (MOUNTAINVIEW POWER PLANT)	SAN BERNARDINO	2005	1054.0	43,862,609	5,749,671	7,629	2,606,536	0.623	49,996,825	6,691,295	7,472	2,971,061	0.725	0.015 ⁽³⁾	1,108.1	1,549,386	1,549,386	148,559	92,077	92,077	1240	10429
	OTAY MESA GENERATING PROJECT	SAN DIEGO	2009	600.0	5,617,964	791,646	7,097	333,848	0.151														
G0861	PALOMAR ESCONDIDO (PALOMAR POWER (SEMPRA ENERGY RESOURCES))	SAN DIEGO	2006	559.0	23,115,079	3,296,813	7,011	1,373,614	0.673	24,986,117	3,590,373	6,959	1,484,800	0.733									
G0797	PASTORIA ENERGY FACILITY (PASTORIA ENERGY FACILITY PHASE 1 & 2, PASTORIA UNIT 1 - UNIT 2)	KERN	2005	760.0	34,618,431	4,979,707	6,952	2,057,200	0.748	34,267,796	4,914,751	6,972	2,036,364	0.738	0.368	779.0	13,989,962	13,989,962	2,514,221	831,401	831,401	661	5564
G0889	SMUD CONSUMNES RIVER PHASE 1 (SMUD CONSUMNES POWER PLANT)	SACRAMENTO	2006	500.0	24,164,354	3,436,323	7,032	1,435,967	0.785	27,111,694	3,838,140	7,064	1,611,112	0.876									
G0784	SUNRISE POWER PROJECT	KERN	2001-SC 2003-CC	572.0	25,139,744	3,581,251	7,020	1,493,929	0.715	26,194,929	3,604,944	7,266	1,556,634	0.719	0.637	605.4	35,635,445	35,635,445	3,378,274	2,107,400	2,107,400	1248	10548
G0779	SUTTER POWER PROJECT (SUTTER-CALPINE, SUTTER EC)	SUTTER	2001	551.8	17,261,195	2,315,457	7,455	1,025,747	0.479	21,561,584	2,898,969	7,438	1,281,297	0.600	0.436	636.0	17,293,068	17,293,068	2,429,452	1,027,703	1,027,703	846	7118
G0648	VALLEY (VALLEY REPOWER)	LOS ANGELES	2004	533.0	18,574,203	2,551,690	7,279	1,103,772	0.547	18,520,679	2,547,518	7,270	1,100,591	0.546		741 ⁽⁴⁾	18,286,822	18,315,262	2,488,485	1,086,768	1,088,459	873	
G0900	WALNUT ENERGY CENTER (TID COMBINED CYCLE, WALNUT ENERGY CENTER, WEC)	STANISLAUS	2006	275 (300.6?)	11,916,521	1,523,778	7,820	708,139	0.579	12,339,979	1,577,680	7,822	733,303	0.599									

Notes: (1) Net Heat Rate (Btu/kWh) = Total Fuel Consumption (MMBtu/year)/Total Net Generation (MWh)
Est'd annual CO₂ (tons) = Total Fuel Consumption (MMBtu/year) x emission rate (~118.85 lb-CO₂/MMBtu input)
"Est'd Capacity Factor" = ("Total Net Generation (MWh)") / ("ONLINE_MW" x 8760)
(2) Data includes ALL generators at the plant -- F-Class and H-Class CTGs,
STGs in combined cycle with CTGs; CTG peakers; STGs supplied by older fired boilers.
(3) Plant commercial operation commenced late in 2005.
(4) Anomaly due to existing STG oversized for HRSG steam output after repower?
(5) May not be accurate due to inconsistencies in monthly reporting.
(6) Adjusted values for heat input and CO₂ emissions exclude portion attributable to
cogeneration steam production.

California Map of NGCC Plants and Potential CO₂ Storage Locations

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