EXHIBIT 1

FEDERAL ENERGY REGULATORY COMMISSION
WASHINGTON, DC 20426

OFFICE OF THE CHAIRMAN

February 20, 2009

The Honorable Bob Filner
U.S. House of Representatives
Washington, D.C. 20515

Dear Representative Filner:

I am responding to your January 16, 2009 letter requesting a corrected definition of G-l in the San Diego Gas and Electric (SDG&E) service territory.

It appears in your letter that there is a disagreement between the transmission operator, California Independent System Operator (CAISO), and the transmission owner, SDG&E, on the appropriate reserve requirements or reserve impact of the combined cycle cogeneration plants. In particular, each of the cogeneration plants consists of two gas-turbine generators whose exhaust gases are directed into a heat recovery steam generator which drives a steam-turbine generator. The units are designed so that the steam can be vented during a steam-turbine generator trip, which will allow the gas turbines to continue to operate. The disagreement arises because the CAISO believes there are still common mode failures that will trip the entire plant (all three turbine generators) and SDG&E claims that a portion of the plant will continue to run (two turbine generators).

The Energy Policy Act of 2005 (EPAct 2005) established section 215 of the Federal Power Act, which authorized the Federal Energy Regulatory Commission (Commission or FERC) to certify an Electric Reliability Organization (ERO) for the purpose of proposing reliability standards for the bulk-power system in the continental United States subject to the Commission's approval. After they are approved by the Commission, the standards are mandatory for the users, owners, and operators of the bulk power system and are enforced by the ERO under the Commission's oversight. The statute also authorized the ERO to delegate enforcement authority to a Regional Entity, subject to Commission approval. In July 2006, the Commission certified the North American Electric Reliability Corporation (NERC) as the ERO. And on June 5, 2007, the Commission accepted executed agreements between NERC and eight Regional Entities, including the Western Electricity Coordinating Council (WECC), in regard to the delegation of NERC's ERO standards development and enforcement authorities to such entities.

WECC is responsible for coordinating and promoting electric system reliability. In addition to promoting a reliable electric power system in the Western Interconnection, WECC provides a forum for resolving transmission access disputes, and provides an environment for coordinating the operating and planning activities of its members as set forth in the WECC Bylaws. The WECC service territory extends from Canada to Mexico. It includes the provinces of Alberta and British Columbia, the northern portion of Baja California, Mexico, and all or portions of the 14 western states in between.

Your request for the Commission to order the CAISO to revise their treatment of the Palomar Energy and Otay Mesa combined cycle projects involve the interpretation and application of the reliability standards by considering specific technical issues that are best first addressed at the Regional Entity level, WECC in this case. The process typically involves a request by the affected entity to the region for a clarification or correction of the application or reliability standard. In this case, SDG&E may appeal the determination by CAISO that an N-1 event for either the Palomar or Otay Mesa plants might cause the loss of all three turbine generators at each site. Commission staff will initiate this process by asking NERC staff to contact SDG&E to determine if they wish to begin the review process.

I hope this information is helpful. Please do not hesitate to get back in touch with me, should you require any additional information.

Sincerely,

Jon Wellinghoff
Acting Chairman

EXHIBIT 2

CAISO Response to Follow-Up Powers Engineering Questions

transmitted by Karen Edson, CAISO, November 7, 2013

Q1: Please reconcile the ISO's use of the "G-1,N-1" contingency in the CPUC's Sunrise Powerlink transmission case and the more recent use of the "N-1, N-1" contingency for setting the bounds of local capacity requirements in the San Diego area. Please address whether the ISO's studies presented in the Sunrise case included contingencies other than "G-1, N-1" and identified the load shedding risk associated with the Sunrise corridor that was ultimately approved.

Response:

As we indicated in the meeting, ISO testimony in the Sunrise proceeding clearly discussed the increased reliability risks associated with the Sunrise route that was ultimately approved compared to the route that was originally proposed. The testimony explained that while the approved corridor still provided significant benefits, it created the risk of 500 and 1000 MW of load shedding. Attachment 1 is the ISO testimony. Below is an excerpt from p. 63:

> "**Q. Please summarize the results for Scenario ASPEN10.**
>
> **A.** Power flow thermal loading, post-transient, and stability analysis was performed on ASPEN10 at the 3500 MW import level under the N-1 conditions and at 4000 MW import level. With the exception of the common mode outage of the two 500 kV lines west of Imperial Valley substation, the performance of this alternative was found to be equivalent to that of the Sunrise Powerlink alternative proposed by SDG&E. ***For the common mode outage of the two 500 kV lines west of Imperial Valley substation, the CAISO found that a Special Protection Scheme would be needed that would shed up to 500 to 1000 MW of load in the San Diego area*** (emphasis added) and 1000 to 2000 MW of generation dropping around Imperial Valley Substation."

The testimony clearly indicates that other contingencies in addition to the "G-1, N-1" contingencies were also studied, and that the need for shedding 500 to 1000 MW of load in San Diego was also identified in those studies. Although the initial, preferred corridor had an advantage over the approved corridor in this regard, the approved corridor still provided significant benefits and the ISO supported the Sunrise project in either configuration.

Q2: Please explain the 1000MW local capacity benefit provided by Sunrise under the N-1, N-1 contingency and why this criteria does not negate the local capacity benefits of the Sunrise project.

Response:

Local capacity requirements are based on the consequences of all relevant outages that must be studied, and then using the largest result to establish the local capacity requirement. In order to isolate the local capacity benefit provided by Sunrise, it is necessary to examine the requirements with and without the Sunrise line in service For context, below is an excerpt from the ISO's "Draft Manual, 2014 Local Capacity Area Technical Study," October 2012.

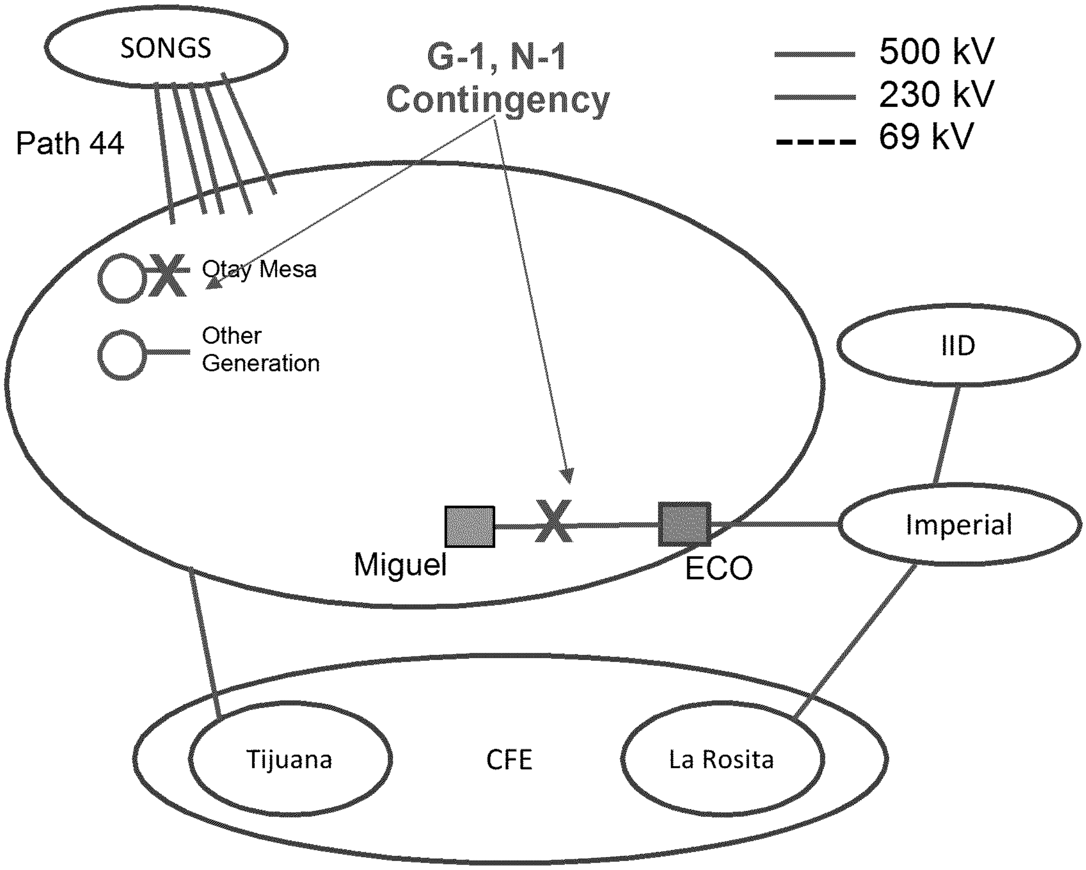
> There are several components of the reliability standards underlying the Technical Study. Consistent with the mandatory nature of the NERC Planning Standards, the ISO is under a statutory obligation to ensure efficient use and reliable operation of the transmission grid consistent with achievement of the NERC Planning Standards. The ISO is further under an obligation, pursuant to its FERC-approved Transmission Control Agreement, to secure compliance with all "Applicable Reliability Criteria." Applicable Reliability Criteria consists of the NERC Planning Standards as well as Local Reliability Criteria, which reflect Reliability Criteria unique to the transmission systems of each participating Transmission Owners ("PTOs").
>
> Pursuant to its tariff authority, the ISO, in consultation with the PTOs and other stakeholders, has adopted ISO Grid Planning Standards intended to, among other things, interpret NERC Planning Standards and identify circumstances in which the ISO should apply standards more stringent than those adopted by NERC. Together, these pre-established criteria form Reliability Criteria to be followed in order to maintain desired performance of the ISO Controlled Grid under Contingency and steady state conditions. The NERC Planning Standards define reliability on interconnected bulk electric systems using the terms "adequacy" and "security." "Adequacy" is the ability of the electric systems to supply the aggregate electrical demand and energy requirements of their customers at all times, taking into account physical characteristics of the transmission system such as transmission ratings and scheduled and reasonably expected unscheduled outages of system elements. "Security" is the ability of the electric systems to withstand sudden disturbances such as electric short circuits or unanticipated loss of system elements. The NERC Planning Standards are organized by Performance Categories. For instance, one category could require that the grid operator not only ensure grid integrity is maintained under certain adverse system conditions, e.g., security, but also that all customers continue to receive electric supply to meet demand, e.g., adequacy. In that case, grid reliability and service reliability would overlap. (pp. 3-4).

<u>Before the construction of Sunrise: G-1,N-1</u>

With everything else comparable, and if the Sunrise project had not been built, the most severe Category B contingency is the G-1 loss of the Otay Mesa generator (605 MW), followed by the N-1 loss of the Imperial Valley-Miguel 500 kV circuit (part of the Southwest Powerlink.

Figure 1: Before Sunrise

G-1, N-1 Contingency



Under these circumstances, the import level into the San Diego area would be 2500 MW, which could be subtracted from the peak load to determine the local capacity requirements. However, the Otay Mesa generator capacity must be added to the local capacity requirements to account for the outage of this unit overlapping with the 500 kV circuit.

The results, for the 2021 load level studies by the ISO, are set out in table 1 below.

Table 1: LCR in San Diego Area Before Sunrise

Study Result	2021 All 4 Scenarios (MW)
1 in 10 Peak Load (latest IEPR, split to Area)	5,749
Import Capability without Sunrise	-2500
Loss of Otay Mesa	+605
LCR: G-1/N-1	**3,854**

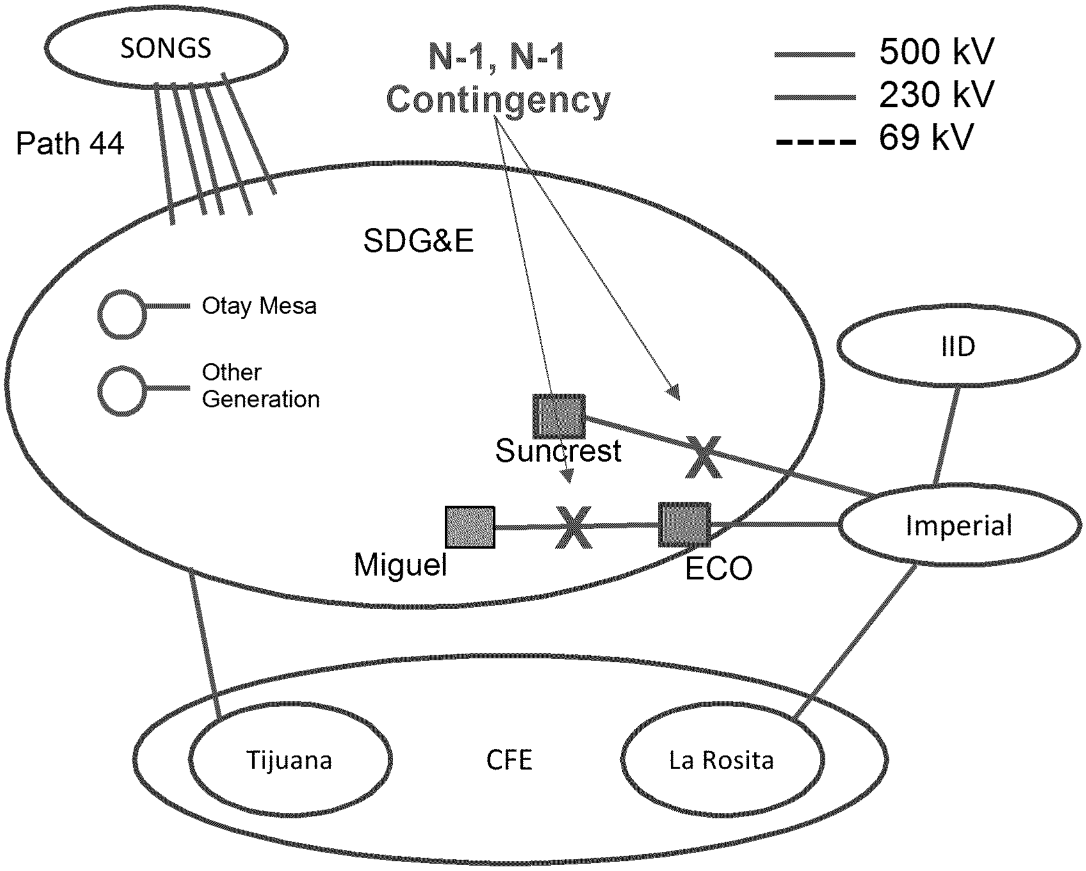
As explained previously, the most severe constraint is used to establish the local capacity requirement. Before Sunrise, the G-1, N-1 contingency described above is more severe that the N-1, N-1 contingency. The N-1, N-1 contingency is the loss of a single 230 kV circuit as part of the Path 44 transfer path (south from SONGS) followed by the loss of the same Imperial Valley-Miguel 500 kV circuit. Because the loss of the Otay Mesa generator is a more significant loss than a single 230 kV circuit, the G-1, N-1 outage results in higher local capacity requirements than the N-1, N-1 outage. Thus, the N-1, N-1 outage was not relevant in establishing local capacity requirements before Sunrise was in service. Further, the system operating limit based on thermal limits were the limiting condition, as that limit was reached before voltage stability limits were encountered.

<u>After the construction of Sunrise: N-1, N-1</u>

Following the construction of the Sunrise project, the most severe G-1, N-1 Category B contingency remains the same as described above. But it is not as severe an N-1, N-1 contingency – the loss of one 500 kV circuit (Sunrise or SWPL), followed by the loss of the other 500 kV circuit. That is because each line is capable delivering much more than the 605 MW produced by Otay Mesa. This N-1, N-1 contingency is described in Figure 2 below.

Figure 2: After Sunrise

N-1, N-1 Contingency



The ISO performed the detailed analysis of each scenario for 2021 and provided its results on Page 3 of the supplemental testimony of Robert Sparks in the Application 11-05-023 proceeding. In this analysis, voltage stability/collapse limits are the limiting condition.

Table 2: LCR in San Diego area After Sunrise

Study Result	2021 All 4 Scenarios (MW)
1 in 10 Peak Load (latest IEPR, split to Area)	5,749
Imports achievable	3086 - 3225
LCR: N-1/N-1	**2,524 – 2,663**

Comparing the results in Table 1 and Table 2 show reductions in local capacity requirements of more than 1,000 MW (1191 MW to 1330 MW) for the four generation scenarios studied. As these results indicate, the Sunrise transmission project on the approved corridor provides well over 1000 MW of reduced local capacity requirement in the San Diego area, as well as the benefits of enabling deliverability of renewable generation east of San Diego.

A significant portion of these local benefits are provided by being able to take credit for the system benefits from the Otay Mesa generation , both because it produces MW that offset the need for imports from outside of the San Diego area, as well because it provides voltage support through its voltage control/excitation system. In addition, the reconfigurations and additions to the 230 kV system in San Diego that were part of the Sunrise project provided additional voltage support benefits. Finally, it must be noted that voltage collapse phenomena are not based on linear equations, and the contributions of different sources to offset a voltage collapse concern cannot always simply be summed arithmetically.

The table below sets out the different system elements available under the two scenarios:

	Before Sunrise, "G-1, N-1" Analysis	**After Sunrise, "N-1, N-1" Analysis**
Sunrise 500 kV Line	No	No
Sunrise related 230 kV reinforcements	No	**YES**
SWPL (Imperial Valley- Miguel 500 kV line)	No	No
Otay Mesa generation (605 MW)	No	**Yes**
Otay Mesa voltage support (functioning voltage control)	No	**Yes**
Limiting condition for the studied contingencies	N-1 thermal limit historically employed for Path 44 for pre-Sunrise system	**Voltage collapse criteria**

Q3: Please provide the ISO planning standards and NERC planning standards:

Response:

Reliability assessment results are measured against the applicable planning standards to determine if system performance criteria have been met according to NERC Transmission Planning Standards, the WECC Transmission Planning System Performance Criteria, and the ISO Planning Standards. The ISO planning standards are developed through stakeholder input and approved by the ISO Board. The current version of the ISO planning standards as well as stakeholder comments for the latest version that was presented to the ISO Board of Governors and approved on July, 2011 is available at:

http://www.caiso.com/informed/Pages/StakeholderProcesses/CompletedStakeholderProcesses/TransmissionPlanningStandards.aspx

A link to the NERC TPL-001, TPL-002, TPL-003, TPL-004 standards is provided below:

Reliability Standards

The relevant WECC criterion is TPL-001-WECC-CRT-2, available at:

http://www.wecc.biz/library/Documentation%20Categorization%20Files/Forms/AllItems.aspx?RootFolder=%2flibrary%2fDocumentation%20Categorization%20Files%2fRegional%20Criteria&FolderCTID=&View=%7bAD6002B2%2d0E39%2d48DD%2dB4B5%2d9AFC9F8A8DB3%7d

Q4: Why does the ISO treat the Palomar and Otay Mesa combined cycle power trains as a single power power plant rather than as separate gas turbines and steam turbines? Can they be considered separate outages instead of a single "plant" outage?

Response:

First, this question is relevant only if the ISO ignores the N-1, N-1 contingency, and focuses instead on only the G-1, N-1 outage. As the ISO has indicated, the N-1, N-1 outage must be considered in establishing the local capacity needs, because it is the most significant, requiring excessive and unacceptable levels of load shedding.

Setting this aside, the ISO has reviewed the outage data it has available for both Otay Mesa and Palomar to see if the actual outage data supports considering the gas turbines and steam turbines as separate outages by meeting the ISO's criteria established in its Planning Standards. The criteria require that the plants have no unplanned, full plant outages for three consecutive years, except for the period immediately following the commissioning of the plant, in which case two years is sufficient.

The ISO cannot release the actual data due to generator confidentiality restrictions, but can summarize the results of its review. (Generator performance data is confidential data owned by the facility owner, therefore, we cannot provide this information. However, an alternative is to request the information directly from the owner.) Setting aside startup outages, the ISO has identified:

- 14 full plant trips of Otay Mesa between Sept 2009 to Sept 2012
- 4 full plant trips of Palomar between July 2009 to July 2012

Based on this review, the data does not support treating the gas turbines and steam turbines as separate generators, but rather continuing treatment as single generators for contingency analysis.

Q5: A question was raised about the profile assumptions related to solar generation and whether the ISO considered all solar generation to use tracking technology.

Response:

The ISO has not assumed all solar resources in California will be tracking. The ISO went through an extensive process for developing minute-by-minute production profiles for solar and wind resources in 2020 based on the expected renewable portfolios defined by the CPUC. These profiles accounted for different solar technologies. The ISO modeled 5,258MW of fixed tilt (2,464, Thin Film Fixed, 1,045MW fixed small solar, 1,749 MW distributed PV) solar PV resources geographically distributed. Only 1,560MW was tracking and 3939MW was solar thermal.

Please refer to the Exhibit 2, of July 1, 2011 Testimony 10-05-006 CPUC LTPP
http://www.caiso.com/Documents/2011-07-01_R10-05-006_Testimony.pdf

EXHIBIT 3

California ISO
Shaping a Renewed Future

Sierra Club

August 21, 2012

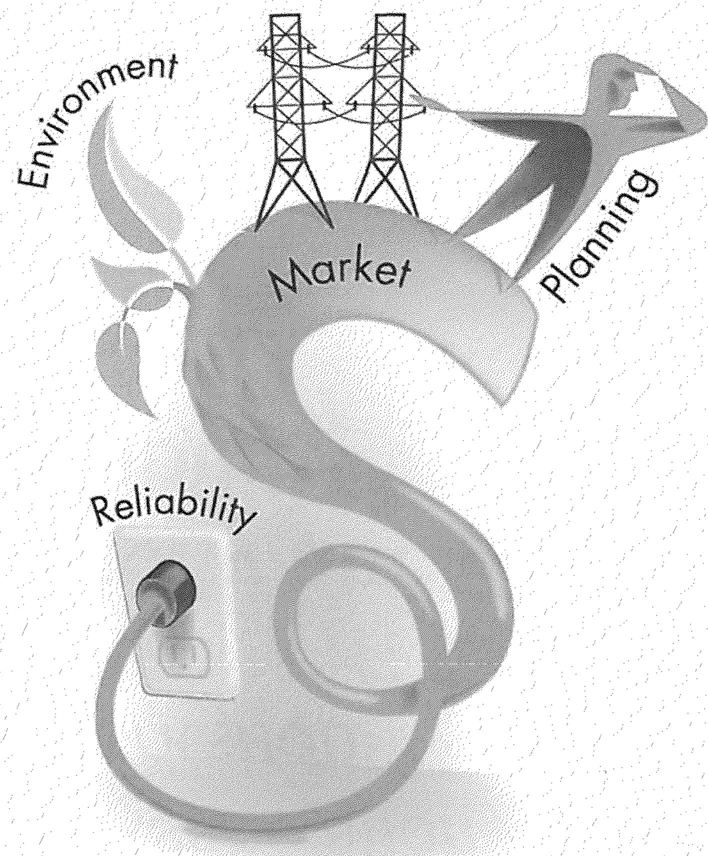
Karen Edson
Vice President, Policy & Client Services

Shaping the industry

The ISO, a nonprofit public benefit corporation, maintains the constant and reliable flow of electricity for the health, safety and welfare of consumers

How?

- Delivering **286 million megawatt-hours** of electricity annually
- Facilitating **fair and transparent** wholesale electricity market
- Performing comprehensive **transmission planning**
- Clearing the way for **clean, green resources** to access the grid



Who oversees us?

We are governed by a governor appointed/ Senate confirmed **Five Member Board**

We are regulated by
FERC Federal Energy Regulatory Commission

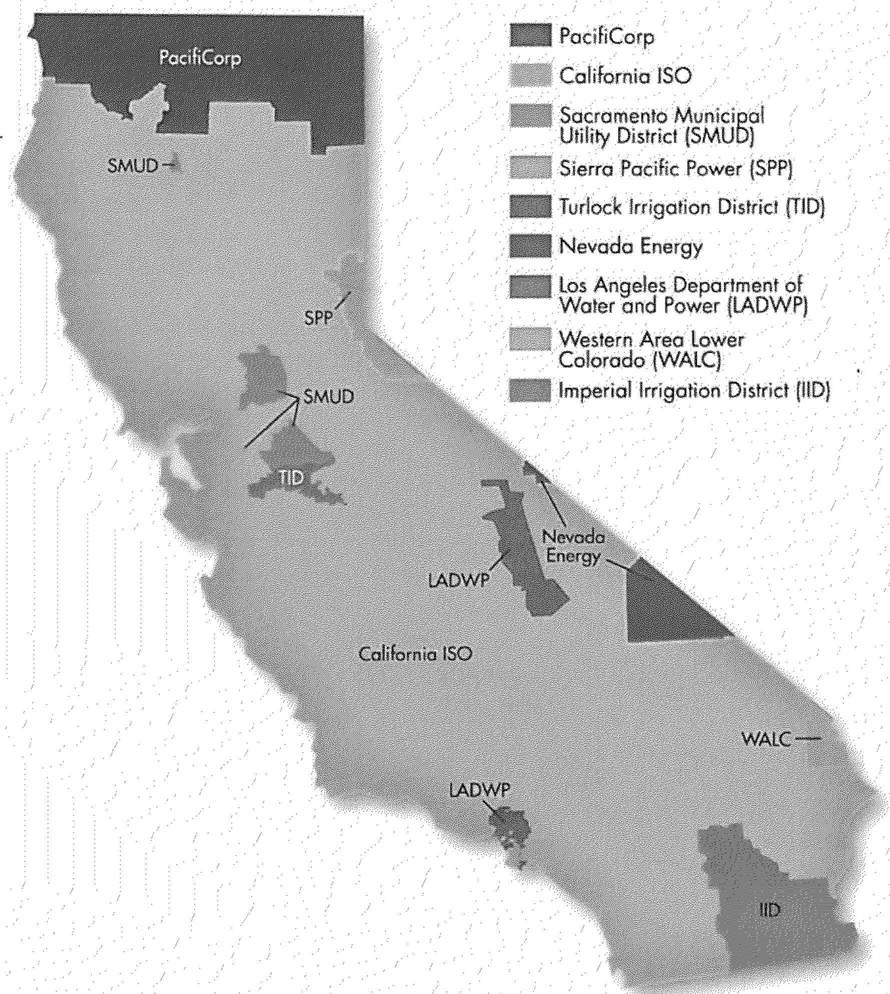
We are compliant with
NERC North American Energy Reliability Corporation

We are part of
WECC Western Electricity Coordinating Council

California ISO
Shaping a Renewed Future

3

California ISO by the numbers



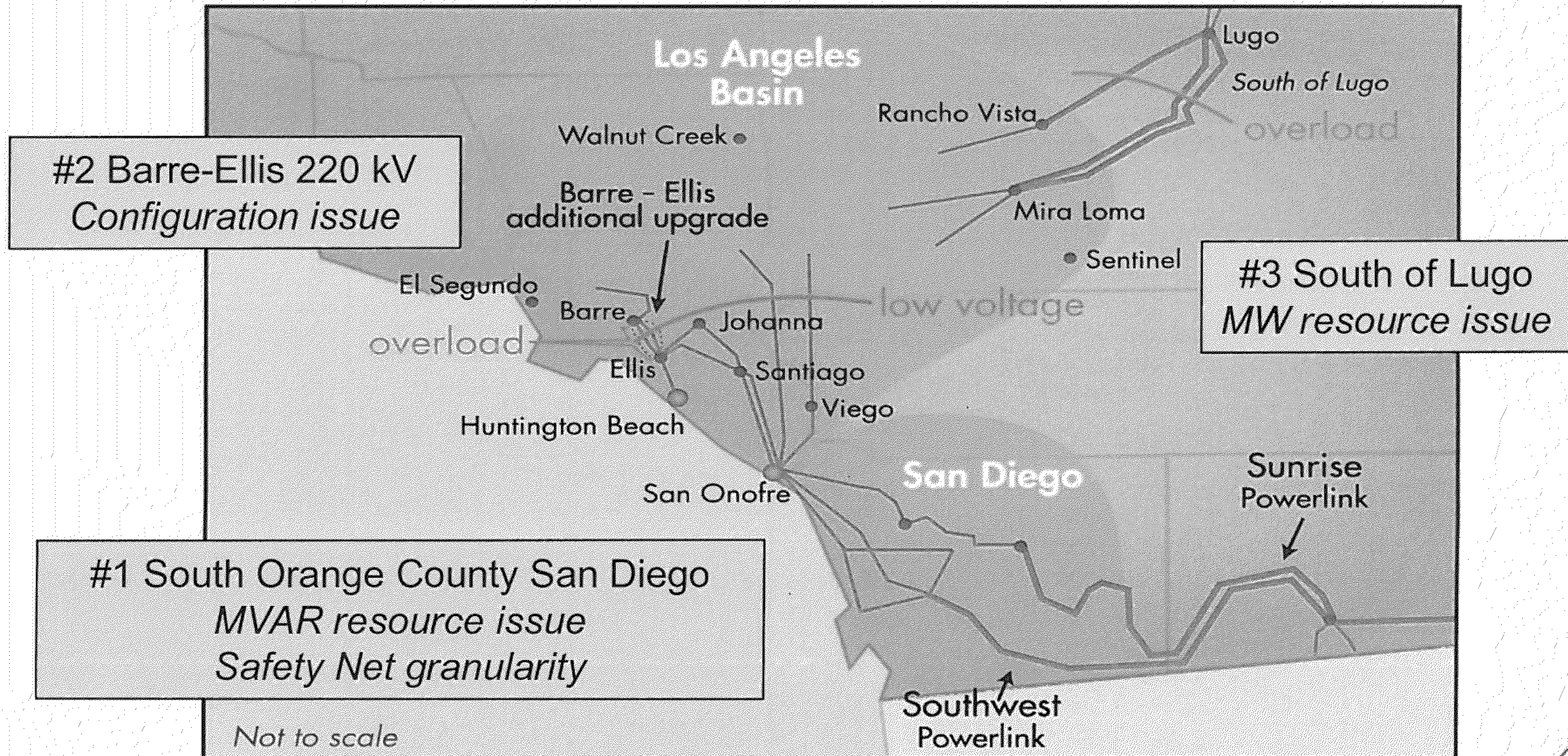
- **57,963** MW of power plant capacity
- **50,270** MW record peak demand (July 24, 2006)
- **30,000** market transactions per day
- **25,865** circuit-miles of transmission lines
- **30 million** people served
- **286 million** megawatt-hours of electricity delivered annually

California ISO
Shaping a Renewed Future

4

Meeting CEC forecast demand without SONGS or Huntington Beach presents reliability challenges.

Focus is on non-generation alternatives to mitigate risk.



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Shaping a Renewed Future

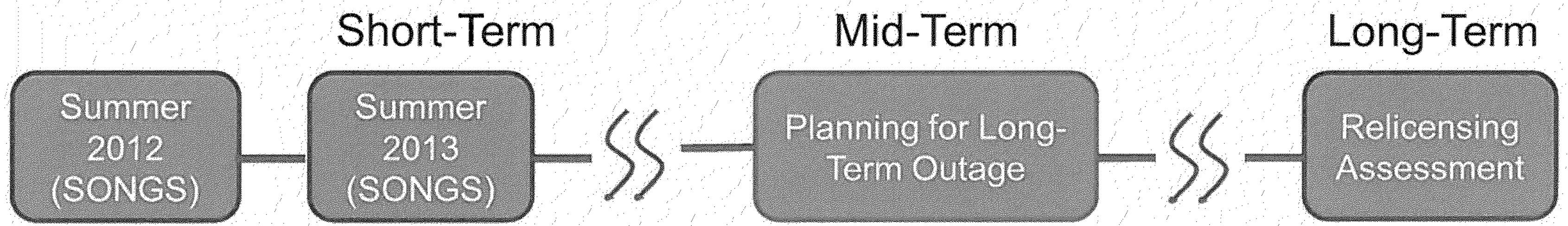
5

Least regrets solutions balance reliability needs without excessive reliance on load-dropping schemes.

1) Convert HB 3 and 4 to synchronous condensers and install capacitors in existing substations
2) Split Barre-Ellis 220 kV (from 2 to 4 lines)
3) Accelerate new resources South of Lugo
   - El Segundo and Sentinel in addition to Walnut Creek
4) More granularity in "safety nets" to minimize load at risk
5) Explore:
   - Increased public building demand response and energy efficiency
   - Additional energy from existing CHP facilities

6

Short-term efforts are directed toward solutions that are viable over the long-term.

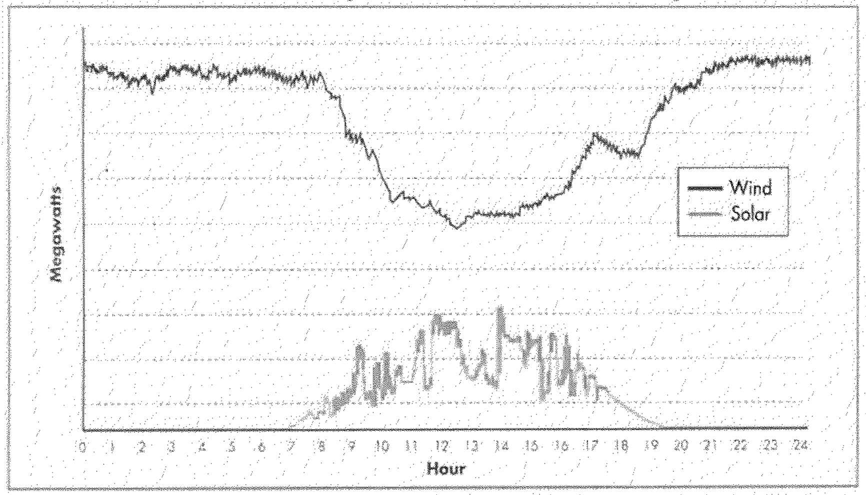


- Maintain reliability
  - Address short-term uncertainty in timely manner
  - Enable transition to long-term solution
- Consider alternatives and changing conditions
  - Factor in variability of demand and resource availability
- Consistent with long-term needs
  - Don't foreclose future options
  - Consider impacts of OTC, voltage support required

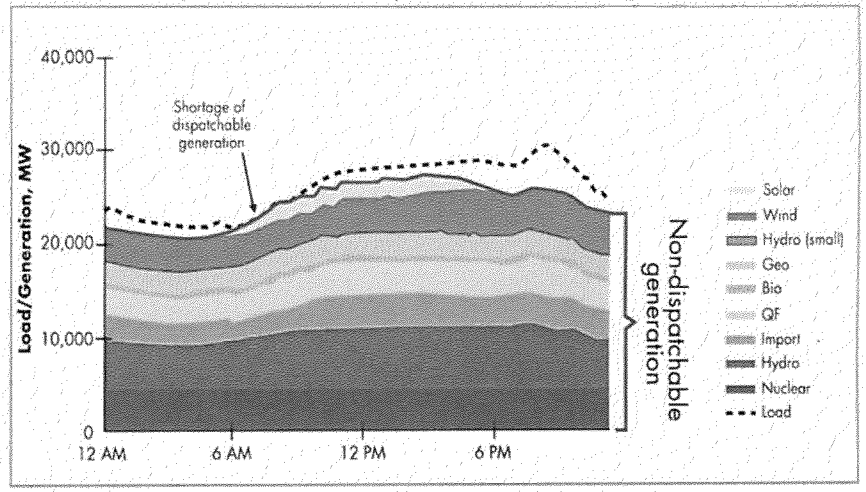
7

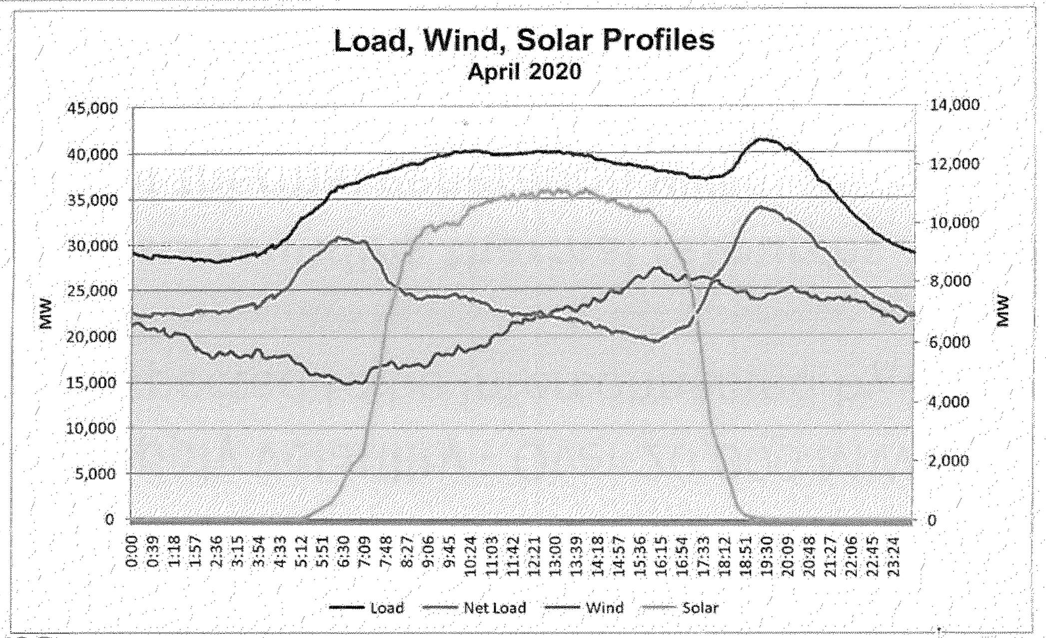
The challenges … to maintain ***cost effective*** reliability

Variability and uncertainty



Dispatchability and Over-generation





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8

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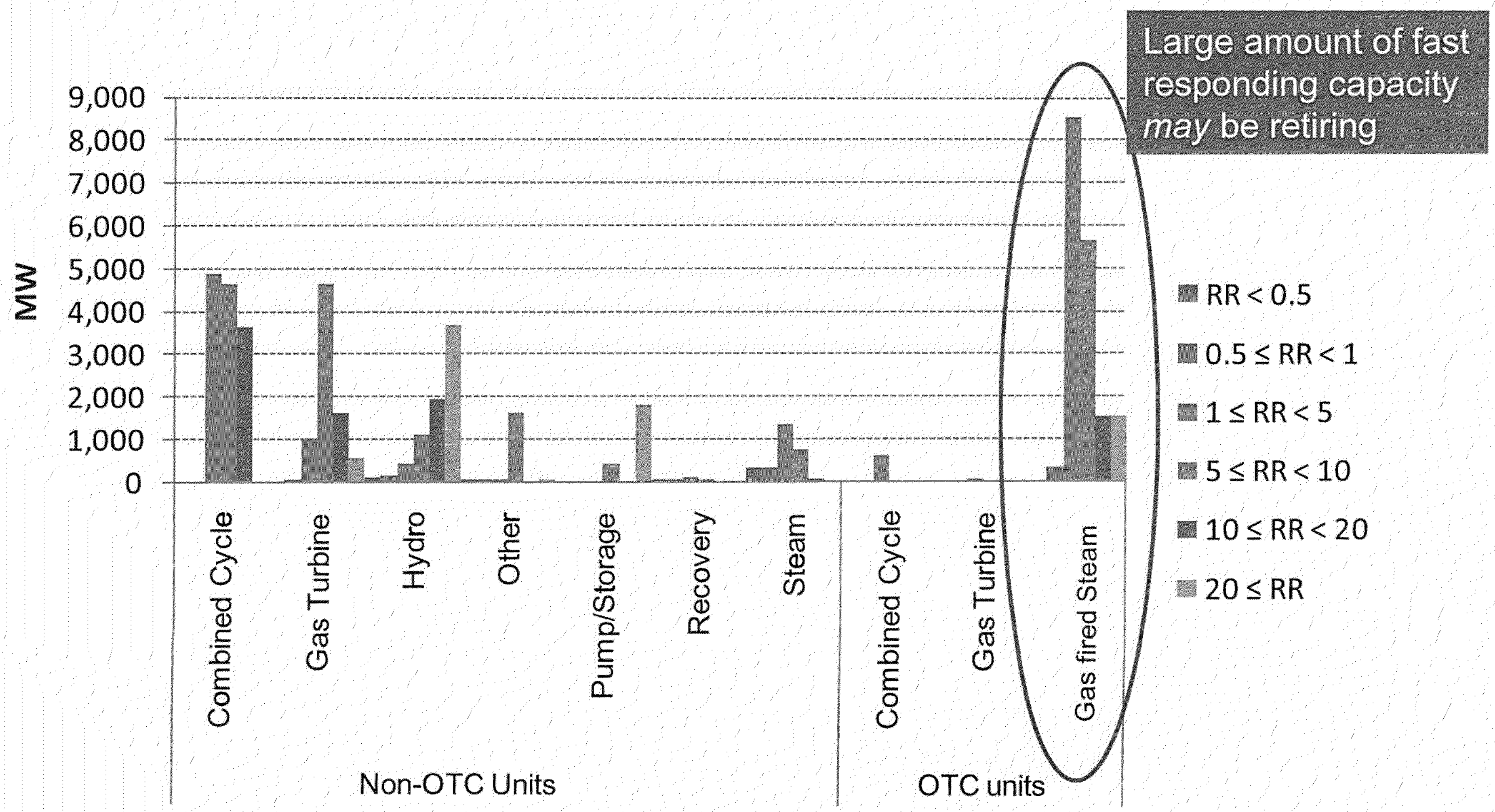
Ramp Rates of the existing CAISO's generation fleet
(MW/min)



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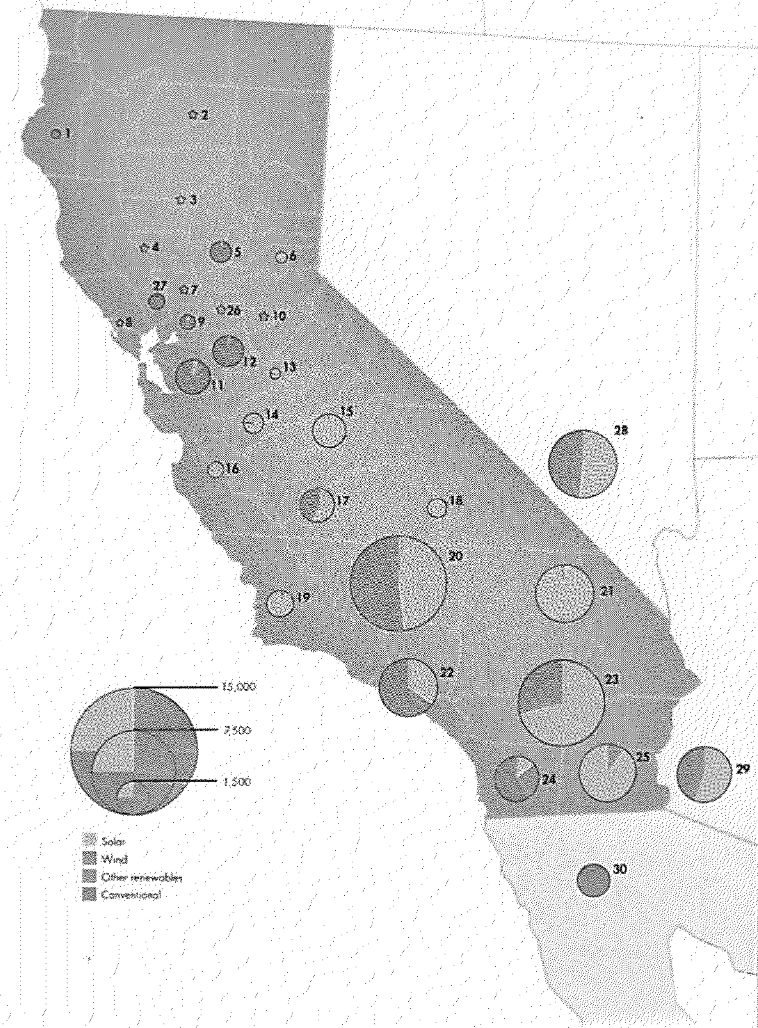
* OTC = Once Through Cooling

9

SB_GT&S_0159325

ISO generation interconnection queue



Interconnection queue by county

County	# of Projects	Megawatts: Renewables	Megawatts: Conventional	Megawatts: Total
1 Humboldt	2	122		122
2 Shasta	1	27		27
3 Butte, Glenn, Tehama	3	29		29
4 Lake, Colusa	1	66		66
5 Sutter, Yuba	2	20	600	620
6 Placer	1	220		220
7 Yolo	2	32		32
8 Marin, Sonoma	3	92		92
9 Solano	4	372		372
10 Amador	1	18		18
11 Alameda, Contra Costa Santa Clara	14	198	1,698	1,896
12 San Joaquin	7	25	1,020	1,045
13 Stanislaus, Tuolumne	4	127		127
14 Merced	3	442		442
15 Fresno, Madera	45	1,685	15	1,700
16 Monterey, San Benito	1	300		300
17 Kings	24	831	625	1,456
18 Tulare, Inyo	8	710		710
19 San Luis Obispo, Santa Barbara	7	901		901
20 Kern	57	8,107	402	8,509
21 San Bernardino	13	3,184		3,184
22 Los Angeles, Orange	35	1,503	2,221	3,724
23 Riverside	22	5,703	1,920	7,623
24 San Diego	20	697	1,068	1,765
25 Imperial	14	2,315		2,315
26 Sacramento	1	20		20
27 Napa	1	301		301
Other*	57	4,453	6,420	10,873
In-state Totals	353	32,500	15,989	48,489
28 Nevada	22	4,865	1,540	6,405
29 Arizona, New Mexico	5	1,578	1,250	2,828
30 Mexico	3	1,120		1,120
Out-of-state Totals	30	7,563	2,790	10,353
TOTAL ALL PROJECTS	**383**	**40,063**	**18,779**	**58,842**

as of April 24, 2012

*Other represents Cluster 5 projects in the request validation process and not represented on map.

California ISO
Shaping a Renewed Future

EXHIBIT 4

SIERRA CLUB DATA REQUEST
SIERRA CLUB- SDG&E DR-01
PIO PICO – A.13-06-015
SDG&E RESPONSE
DATE RECEIVED: AUGUST 26, 2013
DATE RESPONDED: SEPTEMBER 6, 2013

19. Has SDG&E had any discussions or exchanged information with the CAISO or any other entity regarding extending land leases for Cabrillo II? If so, please provide all related documents.

SDG&E Response 19:

SDG&E objects to this question on the grounds that it is vague, overbroad and not reasonably calculated to lead to the discovery of information relevant to this proceeding. SDG&E also objects to this request in that it seeks information that is beyond the scope of this Application and is an attempt to re-litigate the Commission's need determination in D.13-03-029 and the underlying data on which it was reasonably based. Without waiving these objections and subject thereto, SDG&E responds as follows:

Due to the shutdown of SONGS and the increase in local reliability needs, the CAISO has recommended that these units remain in service. See the CAISO April 30, 2013 "2014 Local Capacity Technical Analysis, Final Report and Study Results" on page 100. This report was provided in response to Question 9. It states that the CAISO recommends retaining "the Kearny peakers, Miramar GTs and El Cajon CT generating facilities until the most limiting contingency is mitigated." These units make up Cabrillo II.

In support of this CAISO request, SDG&E is negotiating with NRG to allow the units to remain in service for a limited period; however, no final agreement has been reached. If an agreement is reached, approval will be subject to a separate CPUC approval.

EXHIBIT 5

Southern California Edison
2012 LTPP R.12-03-014

DATA REQUEST SET CEJA_DRA_Sierra Club-SCE-001

To: CEJA_DRA_SIERRA CLUB
Prepared by: Daniel Donaldson
Title: Power Systems Planner
Dated: 08/30/2013

Question 06:

SCE Track 4 testimony states:

SCE chose the Mid-Case Load Serving Entity (LSE) and Balancing Authority forecast updated June 20, 2013.

SCE's CEC load forecast data is consistent with the Track 4 Scoping Memo, Attachment A, and thus, is consistent with the assumption used by the CAISO. (at pp. 13-14)

CAISO's testimony states CAISO relied on the forecasts contained in the 2012 Integrated Energy Policy Report, August 2012 revision. Sparks Test. at 4. Please explain whether SCE used the August 2012 or the June 2013 CEC load forecast. Since SCE has stated that its assumptions are "consistent" with CAISO's assumptions of load forecast, please describe any differences between SCE and CAISO assumptions.

Response to Question 06:

SCE used the August 2012 revision of the *Mid-Case Load Serving Entity (LSE) and Balancing Authority forecast* (attached in SCE testimony Exhibit No. SCE-01/Ch III.A). This excel document was revised on the CEC website in June of 2013. The June 2013 and August 2012 revisions of the *Mid-Case Load Serving Entity (LSE) and Balancing Authority forecast* contain identical 2022 1-10 peak demand values for SCE and SDG&E service territory in Form 1.5d. Both SCE and CAISO utilized the same load forecast value within the *Mid-Case Load Serving Entity (LSE) and Balancing Authority forecast* referred to as "Total SCE TAC Area" however allocated the load differently. In addition to an overall "Total SCE TAC Area" value, the CEC also provides an "LA Basin Subtotal" value. CAISO's allocation matched the "LA Basin Subtotal" value whereas SCE's allocation did not.

EXHIBIT 6

Southern California Edison
2012 LTPP R.12-03-014

DATA REQUEST SET CEJA_DRA_Sierra Club-SCE-001

To: CEJA_DRA_SIERRA CLUB
Prepared by: Jacqueline G. Jones
Title: Sr. Project Manager
Dated: 08/30/2013

Question 01:

On page 10 of SCE's testimony, SCE references 678 MW of preferred resources and energy storage. Can any or all of this 678 MW be filled with the Track 1 authorization? Please explain the relationship between the Track 1 authorization and the 678 MW.

Response to Question 01:

SCE's Track 1 authorization includes 50 MW of energy storage, 150 MW of preferred resources and 400 MW of optional preferred resources. The 678 MW identified in the referenced table are those specific assumptions used in SCE's studies. The 678 MW has no relationship to those resources that can or will actually be procured in the Track 1 solicitation(s). The preferred resources to be acquired to meet the Track 1 authorization will be based on the responding bids and the valuation process results as described in SCE's Track 1 LCR Procurement Plan which was approved by Energy Division on September 4, 2013.

EXHIBIT 7

Southern California Edison
2012 LTPP R.12-03-014

DATA REQUEST SET CEJA_DRA_Sierra Club-SCE-001

To: CEJA_DRA_SIERRA CLUB
Prepared by: Daniel Donaldson
Title: Power Systems Planner
Dated: 08/30/2013

Question 02:

On page 13 of SCE's testimony, SCE states that "[t]o the extent practical, SCE relied on the Revised Scoping Ruling and Memo of the Assigned Commissioner and Administrative Law Judge issued on May 21, 2013." Please describe any differences between the values that SCE used in its Track 4 studies and the values from the May 21, 2013 Revised Scoping Ruling. Please describe the basis for the differences.

Response to Question 02:

SCE utilized a set of preferred resource assumptions which were different than the "*Revised Scoping Ruling and Memo of the Assigned Commissioner and Administrative Law Judge issued on May 21, 2013*" (*2013 Revised Scoping Ruling*). For all scenarios, the quantity of energy efficiency, DG and PV resources was developed by the CEC and are integrated into its load forecast. Demand Response is not used in the load forecast. In addition to the resources embedded in the load forecast, the Preferred Resources Scenario includes increased levels of energy efficiency, demand response, energy storage, and customer side PV. Table III-1 includes the quantity of each resource. These quantities are based on preliminary technical potential studies of demand response, energy efficiency, and customer PV included. Energy storage of 50 MW was chosen based on the LTPP Track 1 authorization.

SCE's overall load forecast is consistent with the values used in the *2013 Revised Scoping Ruling* however the allocation of load within SCE service territory differed. The basis for the difference in load assumption is described in the response to Question #6. The net result of this allocation difference for all scenarios except the Preferred Resources scenario was CAISO modeled an additional 743 MW of load in the LA Basin. For a description of the differences in thermal unit retirements and additions which SCE identified please refer to p.14, lines 12-21 of SCE testimony.

EXHIBIT 8

Southern California Edison
2012 LTPP R.12-03-014

DATA REQUEST SET CEJA_DRA_Sierra Club-SCE-001

To: CEJA_DRA_SIERRA CLUB
Prepared by: Jacqueline G. Jones
Title: Sr. Project Manager
Dated: 08/30/2013

Question 03:

Specifically, did SCE include the total customer-side PV of 336 MW (117 NQC MW by 2018 plus 219 NQC MW by 2022) identified at p. 9 by the Commission's Attachment A in the Revised Scoping Ruling, anywhere in its assessment? Does SCE's conclusion of the need for 500MW of new generation procurement include any of this customer-side PV? How much?

Response to Question 03:

No, the assumptions included in Attachment A only refer to CAISO studies (see Attachment A page 2 line 1). For all scenarios, SCE' s conclusion of the need for 500 MW of new generation procurement includes the customer-side PV to the extent that it is included in the CEC forecast. Those estimates were developed by the CEC. Additional preferred resources were included in the Preferred Resource Scenario (126 MW of customer-side PV). Please see the response to question 2 for further details.

EXHIBIT 9

Southern California Edison
2012 LTPP R.12-03-014

DATA REQUEST SET CEJA_DRA_Sierra Club-SCE-001

To: CEJA_DRA_SIERRA CLUB
Prepared by: Jacqueline G. Jones
Title: Sr. Project Manager
Dated: 08/30/2013

Question 04:

Please answer the same questions as in #3, but referring instead to the Demand Response numbers provided on p. 7 of the Revised Scoping Ruling Attachment A.

Response to Question 04:

No, the assumptions included in Attachment A only refer to CAISO studies (see Attachment A page 2 line 1). Demand Response resources, totaling 426 MW, are included in SCE's Preferred Resource scenario. SCE's conclusion of the need for 500 MW of new generation procurement does not include demand response. Please see the response to question 2 for further details on the Preferred Resource Scenario.

EXHIBIT 10

New Local Distributed Renewables for Transmission Studies

Program	Projects	MW	Prob	Prob Weighted MW	Delivery at Peak	Local Capacity (MW)
RPS	Sol Orchard	15	75%	11.25	40%	5
SEP						
	Phase I	11	75%	8.25	40%	3
	Phase II	11	50%	5.5	40%	2
ReMAT						
	Peaking	20	50%	10	40%	4
	Non peaking	15	50%	7.5	40%	3
RAM						
	Peaking	10	75%	7.5	40%	3
Totals:		**82**		**50**		**20**

Note Forecast ignores whether all this capacity will achieve full deliverability per CAISO studies

EXHIBIT 11

SIERRA CLUB DATA REQUEST
SIERRA CLUB- SDG&E DR-01
PIO PICO – A.13-06-015
SDG&E RESPONSE
DATE RECEIVED: AUGUST 26, 2013
DATE RESPONDED: SEPTEMBER 6, 2013

2. Identify the size and location of all wholesale DG projects operational, under construction, or contacted in San Diego County.

SDG&E Response 02:

SDG&E objects to this question on the grounds that it is vague, overbroad and not reasonably calculated to lead to the discovery of information relevant to this proceeding. SDG&E also objects to this request in that it seeks information that is beyond the scope of this Application and is an attempt to re-litigate the Commission's need determination in D.13-03-029 and the underlying data on which it was reasonably based. Without waiving these objections and subject thereto, SDG&E responds as follows:

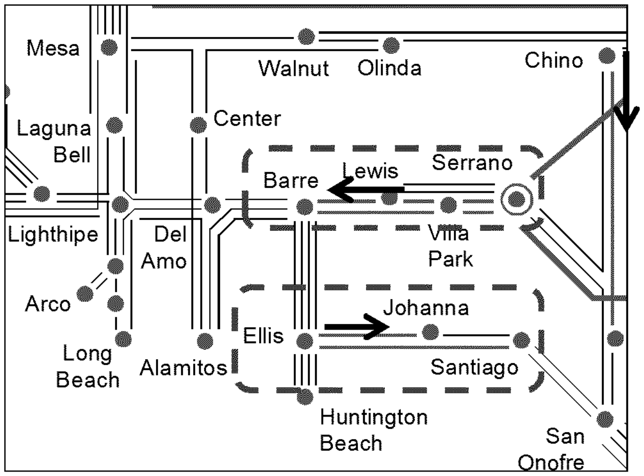
The following list includes all wholesale projects in San Diego County that interconnect at the distribution level (12 kV or below) and are either operational, under construction, or under contract but not yet under construction.

Project Name	Owner	City	Capacity (MW)
AEI MCRD Steam Turbine	Applied Energy Inc.	San Diego	2.58
Badger Filtration Plant	Santa Fe Irrigation District	Rancho Santa Fe	1.485
Badger Filtration Plant	Badger Filtration Plant	Rancho Santa Fe	1.485
Bear Valley	City of Escondido	Escondido	1.5
Buckman Springs PV 1	Fresh Air Energy II	Pine Valley	1.5
Buckman Springs PV 2	Fresh Air Energy II	Pine Valley	1.5
CABRILLO POWER II LLC - EL CAJON GT	CABRILLO POWER II LLC - EL CAJON GT	El Cajon	15
CABRILLO POWER II LLC - ENCINA GT	CABRILLO POWER II LLC - ENCINA GT	Carlsbad	14
Calico Ranch Solar Project	ECOS Energy LLC	Julian	1
City of Escondido Rincon	City of Escondido	Escondido	0.3
City of Oceanside (III)	City of Oceanside	Oceanside	0.5
City of San Diego (Point Loma)	San Diego Metropolitan Wastewater Department	San Diego	6.22
CP - Kelco	CP-Kelco	San Diego	30
Desert Green Solar Farm LLC -	Desert Green Solar Farm LLC	Borrego Springs, CA	5
Global Renewable Energy dba Con Dios Solar 33	Global Renewable Energy dba Con Dios Solar 33 LLC	Valley Center	1.5
GRS (Sycamore 2)	Gas Recovery System, LLC	San Diego	2.5
LanWest Solar Farm LLC	LanWest Solar Farm LLC	2 miles E of Boulevard, CA	5
MM San Diego-Miramar	MM San Diego LLC-Miramar	San Diego	4.5
MM - North City Generating Facility	MM San Diego LLC	San Diego	3.8

SDG&E Response 02-Continued			
MM Prima Deshecha Landfill	MM Prima Deshecha Energy LLC	San Juan Capistrano	6.1
NLP Valley Center Solar	NLP Valley Center Solar	Valley Center	7
North Island Steam Turbine	Applied Energy Inc.	San Diego	4.054
Olivenhain Municipal Water Dist	Olivenhain Municipal Water Dist	San Diego	0.45
Olivenhain Municipal Water District	Olivenhain Municipal Water District	Encinitas	0.45
Otay Landfill 2	Otay Landfill LLC.	Chula Vista	1.5
Otay Landfill 3	Otay Landfill LLC.	Chula Vista	3.8
Otay Landfill I	Otay Landfill LLC.	Chula Vista	1.5
Otay Landfill V	Otay Landfill Gas LLC	San Diego	1.5
Otay Landfill VI	Otay Landfill Gas LLC	San Diego	1.5
Ramona 1	Sol Orchard San Diego 20 LLC	Ramona	2.5
Ramona 2	Sol Orchard San Diego 21 LLC	Ramona	5
Rancho Penasquitos	San Diego County Water Authority	San Diego	4.5
Rodger Miller Hydrogeneration	Olivenhain Municipal Water Dist.	Encinitas	0.45

EXHIBIT 12

Preferred Resource Pilot Targeted Scope

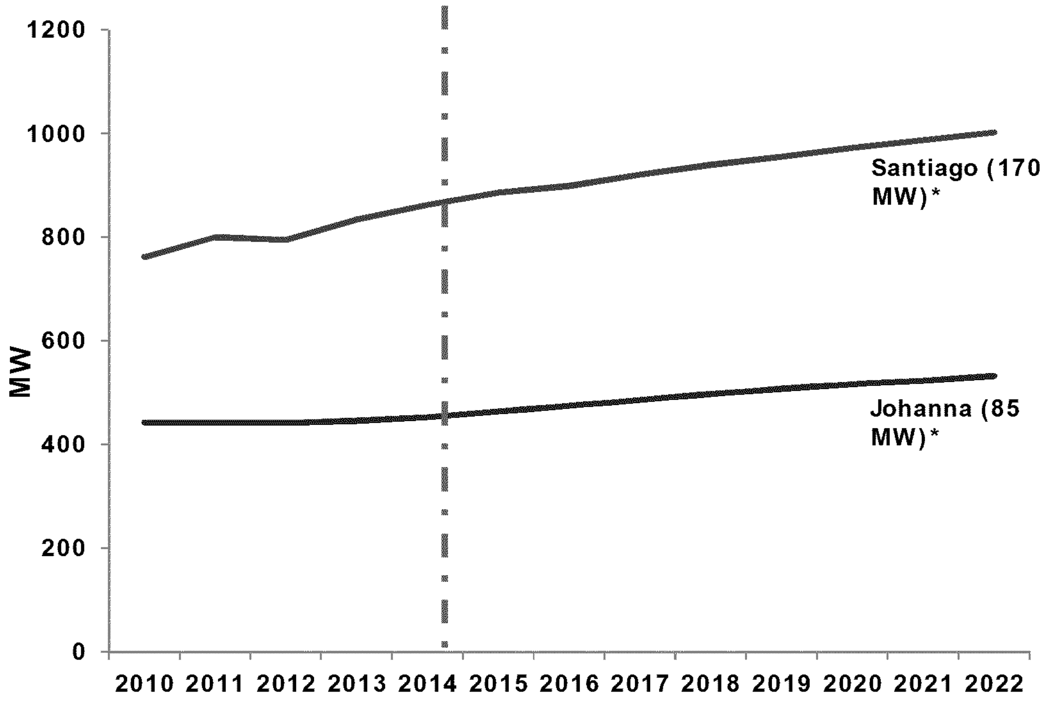


Generation Site	Effectiveness to Resolve Critical Violations			
	Serrano	Vincent	Johanna	Viejo
Huntington	27%	10%	-17%	11%
Alamitos	24%	13%	-7%	4%
Lighthipe	19%	18%	-5%	3%
Rio Hondo	14%	24%	-4%	2%
Mesa	15%	20%	-4%	2%
Johanna	24%	10%	72%	15%
Santiago	21%	9%	58%	19%
San Onofre	8%	7%	35%	33%
North SD	7%	6%	34%	32%

- Transmission contingencies arising in 2020 due to SONGS retirement and OTC[1] plant closures
- Transmission studies show that in 2022 contingencies in the Serrano and Ellis corridors result from insufficient resources during peak demand. Serrano corridor is more constraining than Ellis corridor.
- The Preferred Resource[2] Pilot will explore the suitability of preferred resources in the Johanna & Santiago areas to mitigate contingencies on the Serrano and Ellis corridors.

[1] OTC – once-through cooling
[2] Preferred resources include energy efficiency, demand response, renewable generation and energy storage

Preferred Resource Pilot Scope



- On average, forecast total peak load growth is ~25 MW per year through 2022
- The system is adequate now, but as substation load grows, meeting peak demand is our first reliability constraint and should be our main near term goal (Phase 1)
- If preferred resources can't solve the LCR requirements, there is substantial risk that gas fired generation will be needed as early as 2020

PRP Scope

- Manage load to zero net growth in the Johanna-Santiago vicinity -- unmanaged growth is expected to be about 25 MW/Year
- Identify lessons learned that may be applied to other areas in the West LA basin to address reliability challenges

A key aspect of the pilot will be the identification of the appropriate attributes needed to manage LCR reliability.

Operational and Planning Characteristics Attributes Necessary for Alternative Resources to Meet LCR Needs — **DRAFT** — **For Review Purposes Only**

Attribute Class	Description	Program Example	Activation	Duration	Availability	Frequency of Use	Maximum Participation (MW)	Telemetry Requirement	Triggering Mechanism
A	**Firm Load Reduction**	Energy Efficiency Peak Load Reduction; Permanent Load Shift	N/A	N/A	Dependable capacity during summer peak periods	N/A	None	None	N/A
B	**Customer Side Intermittent Generation**	Customer Rooftop Solar	N/A	N/A	Dependable capacity during summer peak periods	N/A	30% of peak or 80% of light load at circuit level (see note 1)	None	N/A
C	**Real Time Demand Reduction**	Energy Storage Device; Direct Load Control	Automatic activation (post contingency)	At least 4 hours	Annual availability; storage fully charged upon CAISO request up to 60 times/year	At least 3 times/year	None	4-second or 5-minutes, depending on trigger mechanism	Day ahead request to be available; triggered based on CAISO real time instruction or voltage/frequency relay
D.1	**Scheduled Load Reduction (Low Use)**	Demand Response (BIP)	<= 30 minutes (pre contingency)	At least 2 hours	Dependable capacity during summer peak periods (see note 2)	At least 3 times/year	Up to 5% of area peak load	None (observed at A-station)	Triggered based on CAISO instruction; A-station or below
D.2	**Scheduled Load Reduction (Moderate Use)**	Demand Response (SDP)	<= 30 minutes (pre contingency)	At least 4 hours	Dependable capacity during summer peak periods	At least 20 times/year	Up to 20% of peak load (cumulative with D.1)	None (observed at A station)	Triggered based on CAISO instruction; A-station or below
D.3	**Scheduled Load Reduction (High Use)**	Demand Response Contract (with dispatchable EMS)	<= 6 hours (pre contingency)	At least 6 hours	Dependable capacity during summer peak periods	At least 40 times/year	Up to 30% of peak load (cumulative with D.1 & D.2)	None (observed at A station)	Triggered based on CAISO instruction; A-station or below

Note 1: Cumulative; can be waived based on an interconnection study
Note 1: Could be modified to an annual requirement for some/all MW if appropriate

CAISO engagement is critical to the success of the pilot

EXHIBIT 13

Southern California Edison
2012 LTPP R.12-03-014

DATA REQUEST SET CEJA_DRA_Sierra Club-SCE-001

To: CEJA_DRA_SIERRA CLUB
Prepared by: Justin Kubassek
Title: Senior Financial Analyst
Dated: 08/30/2013

Question 10:

Please describe the input values that SCE assumed for energy storage in its Track 4 study including the nameplate and net qualifying capacity. Please describe the basis for this input value or values.

Response to Question 10:

SCE assumed the following values for energy storage:

Number of systems: 5
Nameplate (Power Rating): 10 MW per system
Net Qualifying Capacity: 10 MW per system
Storage Capacity: 4 hours per system
Energy Rating: 40 MWh per system
Fixed O&M Cost: $9.2/kW-yr (2012)
Variable O&M Cost: $0.0014/kWh (2012)
System Cost: $1,983/kW (2020)
Round trip efficiency: 88%
Battery Replacement: 10 years
Battery Cost: 75% of system cost

Please refer to workpaper SCE-1 Ch.IV.A (Pages 51 through 52) for a description of the basis for these input values.

EXHIBIT 14

Conventional Plant Assumptions

CPUC Storage OIR Cost Effectiveness Modeling Input Template

General Assumptions	ESVT Default	Preliminary CT			50MW CT				100MW CT	500MW CCGT	Run #05
Technology	Simple Cycle CT	Hybrid Specs CT	Hybrid Specs CT w/ SPRINT	Hybrid Specs CT High Case	LM6000	LM6000 SPRINT	LM6000	LM6000 SPRINT	LMS100 SAC	CCGT	LM6000 SPRINT
Installation Year		2015	2015	2015	2015	2015	2020	2020	2020	2020	2020
Maximum Plant Life	20	20	20	20	20	20	20	20	20	20	20
Capacity / Discharge - Nameplate		100	100	100	50	50	50	50	100	500	50
Capacity / Discharge - Effective (Derated)											
Derate Temperature #1		32	32	32	32	32	32	32	32	32	32
Derate Temperature #2		50	50	50	50	50	50	50	50	50	50
Derate Temperature #3		68	68	68	68	68	68	68	68	68	68
Derate Temperature #4 (summer peak ~ 30C = 86F)		86	86	86	86	86	86	86	86	86	86
Derate Capacity #4		64	88	?	32	44	32	44	98	490	44
Discharge Duration	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Performance Assumptions	ESVT Default										
Optimal Efficiency - Heat Rate or AC to AC Roundtrip Efficiency	9,300	9,447	9,387	?	9,447	9,387	9,447	9,387	8,628	6,940	9,387
Efficiency: Temperature -Dependent Heat Rate or AC to AC Roundtrip Efficiency											
Derate Temperature #4 (summer peak ~ 30C = 86F)		86	86	86	86	86	86	86	86	86	86
Derate Efficiency #4		110%	105%	?	110%	105%	110%	105%	105%	105%	105%
Efficiency: Load-Dependent Heat Rate or AC to AC Roundtrip Efficiency											
Derate Percent of Full Load #1	20%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%
Derate Percent of Full Load #2	30%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
Derate Percent of Full Load #3	85%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%
Derate Percent of Full Load #4 (Full Load)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Derate Efficiency #1	165%	140%	140%	?	140%	140%	140%	140%	122%	122%	140%
Derate Efficiency #2	124%	129%	128%	?	129%	128%	129%	128%	113%	113%	128%
Derate Efficiency #3	107%	105%	107%	?	105%	107%	105%	107%	102%	102%	107%
Derate Efficiency #4	100%	100%	100%	?	100%	100%	100%	100%	100%	100%	100%

CAPEX Assumptions	ESVT Default										
Total Overnight CAPEX	$1,200	$1,244	$1,535	$1,545	$1,329	$1,619	$1,329	$1,619	$1,535	$1,372	$1,619

OPEX Assumptions	ESVT Default										
Variable O&M											
Variable O&M	$5.0000	$0.8829	$4.1685	$9.0519	$4.1685	$4.1685	$4.1685	$4.1685	$4.1685	$3.0208	$4.1685
Fixed O&M	$15.00	$6.68	$17.40	$42.44	$17.40	$17.40	$17.40	$17.40	$17.40	$8.30	$17.40
Start-Up Fuel Requirement	?	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80
Start-Up Cost	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Minimum Operating Level	20.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%

Modeling Run Assumptions

Run #06	Run #07	Run #14	Run #15	Run #31	Run #32	Run #43	Units	Applicable Technologies	Source
LM6000 SPRINT	LMS100 SAC	LM6000 SPRINT	LM6000 SPRINT	LM6000 SPRINT	LM6000 SPRINT	CCGT		All	
2020	2020	2020	2020	2020	2020	2020	yr	All	
20	20	20	20	20	20	20	yr	All	CEC 2009 COG Study
50	100	50	50	50	50	500	MW	All	
32	32	32	32	32	32	32	DegF	All	GE LM6000 Specs
50	50	50	50	50	50	50	DegF	All	GE LM6000 Specs
68	68	68	68	68	68	68	DegF	All	GE LM6000 Specs
86	86	86	86	86	86	86	DegF	All	GE LM6000 Specs
44	98	44	44	44	44	490	MW	All	GE LM6000 Specs
N/A	N/A	N/A	N/A	N/A	N/A	N/A	h	All Storage	
							Units	Applicable Technologies	Source
9,387	8,628	9,387	9,387	9,387	9,387	6,940	Btu/kWh HHV or %	All	GE LM6000 Specs
86	86	86	86	86	86	86	DegF	All Except Pumped Storage	GE LM6000 Specs
105%	105%	105%	105%	105%	105%	105%	% of optimal efficiency	All Except Pumped Storage	GE LM6000 Specs
40%	40%	40%	40%	40%	40%	40%	load as % of full capaci	All Except Pumped Storage	GE LM6000 Specs
50%	50%	50%	50%	50%	50%	50%	load as % of full capaci	All Except Pumped Storage	GE LM6000 Specs
80%	80%	80%	80%	80%	80%	80%	load as % of full capaci	All Except Pumped Storage	GE LM6000 Specs
100%	100%	100%	100%	100%	100%	100%	load as % of full capaci	All Except Pumped Storage	GE LM6000 Specs
140%	122%	140%	140%	140%	140%	122%	% of optimal efficiency	All Except Pumped Storage	EPRI Default
128%	113%	128%	128%	128%	128%	113%	% of optimal efficiency	All Except Pumped Storage	GE LM6000 Specs
107%	102%	107%	107%	107%	107%	102%	% of optimal efficiency	All Except Pumped Storage	GE LM6000 Specs
100%	100%	100%	100%	100%	100%	100%	% of optimal efficiency	All Except Pumped Storage	GE LM6000 Specs
							Units	Applicable Technologies	Source
$1,619	$1,535	$1,619	$1,619	$1,619	$1,619	$1,372	$/kW	All	
							Units	Applicable Technologies	Source
$4.1685	$4.1685	$4.1685	$4.1685	$4.1685	$4.1685	$3.0208	$/MWh	All	CEC 2009 COG Study
$17.40	$17.40	$17.40	$17.40	$17.40	$17.40	$8.30	$/kW-yr	All	CEC 2009 COG Study
2.80	2.80	2.80	2.80	2.80	2.80	2.80	MMBtu/MW	CAES/CT	CEC 2009 COG Study
N/A	N/A	N/A	N/A	N/A	N/A	N/A	$/Start	Pumped Storage	
40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	% of Discharge Capacit	CAES/CT	GE LM6000 Specs

Notes

Technology that assumptions are based on
Year project is online and align with specs and costs

Useful/planned operational life

Nameplate discharge capacity

Temperature selected to specify derated capacity #1
Temperature selected to specify derated capacity #2
Temperature selected to specify derated capacity #3
Temperature selected to specify derated capacity #4
Derated capacity at temperature #4

Discharge duration at nameplate capacity

Notes

Efficiency at optimal load, temperature, and ramp

Temperature selected to specify derated efficiency #4
Derated efficiency at temperature #4

Percent of full load selected to specify derated efficiency #1
Percent of full load selected to specify derated efficiency #2
Percent of full load selected to specify derated efficiency #3
Percent of full load selected to specify derated efficiency #4
Derated efficiency at percent of full load #1
Derated efficiency at percent of full load #2
Derated efficiency at percent of full load #3
Derated efficiency at percent of full load #4

Notes

Calculated

Notes

Consumables such as water supply costs, etc.; excludes fuel costs
Labor, etc.

Fuel use per start-up
Costs associated with startup of pumped storage turbine
Pmin of turbine

EXHIBIT 15

Storage Plant Assumptions

CPUC Storage OIR Cost Effectiveness Modeling Input Template

General Assumptions	ESVT Default	50MW Battery						20MW Battery - Short Duration		1MW I
Technology		Battery - 4h	Battery - 4h	Battery - 3h	Battery - 3h	Battery - 2h	Battery - 2h	Battery - Short Duration	Battery - Short Duration	Battery - 4h
Installation Year		2015	2020	2015	2020	2015	2020	2015	2020	2015
Maximum Plant Life		20	20	20	20	20	20	20	20	20
Capacity / Discharge - Nameplate		50	50	50	50	50	50	20	20	1
Capacity / Discharge - Effective (Derated)										
Derate Temperature #4 (summer peak ~ 30C = 86F)		105	105	105	105	105	105	105	105	105
Derate Capacity #4		50	50	50	50	50	50	20	20	1
Discharge Duration		4	4	3	3	2	2	0.25	0.25	4
Capacity / Charge - Nameplate		50	50	50	50	50	50	20	20	1
Capacity / Charge - Effective (Derated)										
Derate Temperature #4 (summer peak ~ 30C = 86F)		86	86	86	86	86	86	86	86	86
Derate Capacity #4		50	50	50	50	50	50	20	20	1
Performance Assumptions	**ESVT Default**									
Optimal Efficiency - Heat Rate or AC to AC Roundtrip Efficiency		83%	83%	83%	83%	83%	83%	83%	83%	83%
Efficiency: Temperature -Dependent Heat Rate or AC to AC Roundtrip Efficiency										
Derate Temperature #4 (summer peak ~ 30C = 86F)		86	86	86	86	86	86	86	86	86
Derate Efficiency #4		100%	100%	100%	100%	100%	100%	100%	100%	100%
Efficiency: Load-Dependent Heat Rate or AC to AC Roundtrip Efficiency										
Derate Percent of Full Load #1		20%	20%	20%	20%	20%	20%	20%	20%	20%
Derate Percent of Full Load #2		30%	30%	30%	30%	30%	30%	30%	30%	30%
Derate Percent of Full Load #3		85%	85%	85%	85%	85%	85%	85%	85%	85%
Derate Percent of Full Load #4 (Full Load)		100%	100%	100%	100%	100%	100%	100%	100%	100%
Derate Efficiency #1		100%	100%	100%	100%	100%	100%	100%	100%	100%
Derate Efficiency #2		100%	100%	100%	100%	100%	100%	100%	100%	100%
Derate Efficiency #3		100%	100%	100%	100%	100%	100%	100%	100%	100%
Derate Efficiency #4		100%	100%	100%	100%	100%	100%	100%	100%	100%
Degradation Schedules										
Calendar Year Degradation (Duration/Energy)		2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%
CAPEX Assumptions	**ESVT Default**									
Total Overnight CAPEX		$2,011	$1,761	$1,606	$1,406	$1,206	$1,056	$1,015	$765	$2,000
OPEX Assumptions	**ESVT Default**									

Variable O&M										
Variable O&M		$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$0.2500
Fixed O&M		$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00
Replacement Costs as $/kWh	$0	$250	$250	$250	$250	$250	$250	$250	$250	$250
Replacement Cost Reduction Over Time	0%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Energy Charge Ratio		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Start-Up Fuel Requirement		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Start-Up Cost		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Minimum Operating Level		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Compressor Efficiency		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Minimum Pump Load		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Minimum Turbine Load		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pump Efficiency		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Turbine Efficiency		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Allow Simultaneous Compression and Generation?		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Cycle Life Assumptions	ESVT Default									
Cycle Life by Depth of Discharge (DoD)										
DoD Segment #1	0-3%	0-3%	0-3%	0-3%	0-3%	0-3%	0-3%	0-3%	0-3%	0-3%
DoD Segment #2	3-10%	3-10%	3-10%	3-10%	3-10%	3-10%	3-10%	3-10%	3-10%	3-10%
DoD Segment #3	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%
DoD Segment #4	20-30%	20-30%	20-30%	20-30%	20-30%	20-30%	20-30%	20-30%	20-30%	20-30%
DoD Segment #5	30-40%	30-40%	30-40%	30-40%	30-40%	30-40%	30-40%	30-40%	30-40%	30-40%
DoD Segment #6	40-50%	40-50%	40-50%	40-50%	40-50%	40-50%	40-50%	40-50%	40-50%	40-50%
DoD Segment #7	50-60%	50-60%	50-60%	50-60%	50-60%	50-60%	50-60%	50-60%	50-60%	50-60%
DoD Segment #8	60-70%	60-70%	60-70%	60-70%	60-70%	60-70%	60-70%	60-70%	60-70%	60-70%
DoD Segment #9	70-80%	70-80%	70-80%	70-80%	70-80%	70-80%	70-80%	70-80%	70-80%	70-80%
Cycle Life at DoD Segment #1	1,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000
Cycle Life at DoD Segment #2	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000
Cycle Life at DoD Segment #3	80,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
Cycle Life at DoD Segment #4	30,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000
Cycle Life at DoD Segment #5	15,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000
Cycle Life at DoD Segment #6	8,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000
Cycle Life at DoD Segment #7	5,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Cycle Life at DoD Segment #8	4,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000
Cycle Life at DoD Segment #9	3,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000

Battery	0.5MW Battery		0.25MW Battery		50MW Flow Battery		1MW Flow Battery		Flywheel		Pumped Storage		Above Gr
Battery - 4h	Battery - 4h	Battery - 4h	Battery - 2h	Battery - 2h	Flow Battery	Flow Battery	Flow Battery	Flow Battery	Flywheel	Flywheel	Pumped Storage	Pumped Storage	Above Ground CAES
2020	2015	2020	2015	2020	2015	2020	2015	2020	2015	2020	2020	2020	2020
20	20	20	20	20	17	20	17	20	20	20	100	100	35
1	0.500	0.500	0.250	0.250	50	50	1	1	20	20	300	300	100
105	105	105	105	105	105	105	105	105	105	105	105	105	105
1	0.500	0.500	0.250	0.250	50	50	1	1	20	20	300	300	100
4	4	4	2	2	4	4	4	4	0.25	0.25	8	11	5
1	0.500	0.500	0.250	0.250	50	50	1	1	20	20	350	350	100
86	86	86	86	86	86	86	86	86	86	86	86	86	86
1	0.500	0.500	0.250	0.250	50	50	1	1	20	20	350	350	100
83%	83%	83%	83%	83%	70%	75%	70%	75%	84%	84%	82.5%	82.5%	3,810
86	86	86	86	86	86	86	86	86	86	86	86	86	86
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	105%
20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	25%
30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	50%
85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	75%
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	109%
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	104%
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	101%
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2.00%	2.00%	2.00%	2.00%	2.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$1,750	$2,000	$1,750	$1,200	$1,050	$2,022	$1,772	$3,100	$2,850	$1,788	$1,538	$1,325	$1,426	$1,214

$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$0.0000	$0.0000	$1.0200	$1.0200	$3.0000
$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$43.00	$43.00	$7.50	$7.50	$5.00
$250	$250	$250	$250	$250	$0	$0	$0	$0	$0	$0	$6.63	$7.16	$0
2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%

N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.70
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$0	$0	$0
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	20.0%
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	96.0%
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	58.6%	58.6%	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	25.0%	25.0%	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	See Curves	See Curves	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	See Curves	See Curves	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Yes

0-3%	0-3%	0-3%	0-3%	0-3%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3-10%	3-10%	3-10%	3-10%	3-10%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10-20%	10-20%	10-20%	10-20%	10-20%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
20-30%	20-30%	20-30%	20-30%	20-30%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
30-40%	30-40%	30-40%	30-40%	30-40%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
40-50%	40-50%	40-50%	40-50%	40-50%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
50-60%	50-60%	50-60%	50-60%	50-60%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
60-70%	60-70%	60-70%	60-70%	60-70%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
70-80%	70-80%	70-80%	70-80%	70-80%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
500,000	500,000	500,000	500,000	500,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
100,000	100,000	100,000	100,000	100,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
45,000	45,000	45,000	45,000	45,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
20,000	20,000	20,000	20,000	20,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
14,000	14,000	14,000	14,000	14,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10,000	10,000	10,000	10,000	10,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8,000	8,000	8,000	8,000	8,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4,000	4,000	4,000	4,000	4,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

ound CAES	Run #01	Run #02	Run #03	Run #04	Run #08	Run #09	Run #10	Run #11	Run #12	Run #13	Run #16	Run #17	Run #18
Above Ground CAES	Battery - 2h	Battery - 2h	Battery - 3h	Battery - 4h	Battery - 2h	Battery - 2h	Battery - 2h	Battery - 2h	Battery - 2h	Battery - 2h	Flow Battery	Pumped Storage	Above Ground CAES
2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020
35	20	20	20	20	20	20	20	20	20	20	20	100	35
100	50	50	50	50	50	50	50	50	50	50	50	300	100
105	105	105	105	105	105	105	105	105	105	105	105	105	105
100	50	50	50	50	50	50	50	50	50	50	50	300	100
8	2	2	3	4	2	2	2	2	2	2	4	8	8
100	50	50	50	50	50	50	50	50	50	50	50	350	100
86	86	86	86	86	86	86	86	86	86	86	86	86	86
100	50	50	50	50	50	50	50	50	50	50	50	350	100
3,810	83%	83%	83%	83%	83%	83%	83%	83%	83%	83%	75%	82.5%	3,810
86	86	86	86	86	86	86	86	86	86	86	86	86	86
105%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	105%
25%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	25%
50%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	50%
75%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	75%
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
109%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	109%
104%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	104%
101%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	101%
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
0.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	0.00%	0.00%	0.00%
$1,684	$1,056	$1,056	$1,406	$1,761	$1,056	$1,056	$1,056	$1,056	$1,056	$1,056	$1,772	$1,325	$1,684

$3.0000	$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$1.0200	$3.0000
$5.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$7.50	$5.00
$0	$250	$250	$250	$250	$250	$250	$250	$250	$250	$250	$0	$6.63	$0
2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%

0.70	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.70
N/A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	N/A	N/A
$0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$0	$0
20.0%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	20.0%
96.0%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	96.0%
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	58.6%	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	25.0%	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	See Curves	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	See Curves	N/A
Yes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Yes

N/A	0-3%	0-3%	0-3%	0-3%	0-3%	0-3%	0-3%	0-3%	0-3%	0-3%	N/A	N/A	N/A
N/A	3-10%	3-10%	3-10%	3-10%	3-10%	3-10%	3-10%	3-10%	3-10%	3-10%	N/A	N/A	N/A
N/A	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	N/A	N/A	N/A
N/A	20-30%	20-30%	20-30%	20-30%	20-30%	20-30%	20-30%	20-30%	20-30%	20-30%	N/A	N/A	N/A
N/A	30-40%	30-40%	30-40%	30-40%	30-40%	30-40%	30-40%	30-40%	30-40%	30-40%	N/A	N/A	N/A
N/A	40-50%	40-50%	40-50%	40-50%	40-50%	40-50%	40-50%	40-50%	40-50%	40-50%	N/A	N/A	N/A
N/A	50-60%	50-60%	50-60%	50-60%	50-60%	50-60%	50-60%	50-60%	50-60%	50-60%	N/A	N/A	N/A
N/A	60-70%	60-70%	60-70%	60-70%	60-70%	60-70%	60-70%	60-70%	60-70%	60-70%	N/A	N/A	N/A
N/A	70-80%	70-80%	70-80%	70-80%	70-80%	70-80%	70-80%	70-80%	70-80%	70-80%	N/A	N/A	N/A
N/A	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	N/A	N/A	N/A
N/A	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	N/A	N/A	N/A
N/A	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	N/A	N/A	N/A
N/A	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	N/A	N/A	N/A
N/A	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	N/A	N/A	N/A
N/A	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	N/A	N/A	N/A
N/A	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	N/A	N/A	N/A
N/A	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	N/A	N/A	N/A
N/A	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	N/A	N/A	N/A

Modeling Run Assumptions

Run #19	Run #20	Run #21	Run #22	Run #23	Run #24	Run #25	Run #26	Run #27	Run #28	Run #29	Run #30	Run #33	Run #34	Run #35
Battery - Short Duration	Battery - 2h	Battery - 2h	Battery - 4h	Battery - 4h	Battery - 4h	Battery - 4h	Flow Battery	Battery - 2h	Battery - 2h	Battery - 2h	Battery - 2h	Battery - 2h	Battery - 2h	Battery - 4h
2020	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2020	2020	2020	2020
20	20	20	20	20	20	20	17	20	20	20	20	20	20	20
20	50	50	1	1	1	1	1	0.250	0.250	0.250	50	50	50	1
105	105	105	105	105	105	105	105	105	105	105	105	105	105	105
20	50	50	1	1	1	1	1	0.250	0.250	0.250	50	50	50	1
0.25	2	2	4	4	4	4	4	2	2	2	2	2	2	4
20	50	50	1	1	1	1	1	0.250	0.250	0.250	50	50	50	1
86	86	86	86	86	86	86	86	86	86	86	86	86	86	86
20	50	50	1	1	1	1	1	0.250	0.250	0.250	50	50	50	1
83%	83%	83%	83%	83%	83%	83%	70%	83%	83%	83%	83%	83%	83%	83%
86	86	86	86	86	86	86	86	86	86	86	86	86	86	86
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%
85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	0.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%
$778	$1,206	$1,206	$2,000	$2,000	$2,000	$2,000	$3,100	$1,200	$1,200	$1,200	$1,056	$1,056	$1,056	$1,750

$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$0.2500
$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00
$250	$250	$250	$250	$250	$250	$250	$0	$250	$250	$250	$250	$250	$250	$250
2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%

N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

0-3%	0-3%	0-3%	0-3%	0-3%	0-3%	0-3%	N/A	0-3%	0-3%	0-3%	0-3%	0-3%	0-3%	0-3%
3-10%	3-10%	3-10%	3-10%	3-10%	3-10%	3-10%	N/A	3-10%	3-10%	3-10%	3-10%	3-10%	3-10%	3-10%
10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	N/A	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%	10-20%
20-30%	20-30%	20-30%	20-30%	20-30%	20-30%	20-30%	N/A	20-30%	20-30%	20-30%	20-30%	20-30%	20-30%	20-30%
30-40%	30-40%	30-40%	30-40%	30-40%	30-40%	30-40%	N/A	30-40%	30-40%	30-40%	30-40%	30-40%	30-40%	30-40%
40-50%	40-50%	40-50%	40-50%	40-50%	40-50%	40-50%	N/A	40-50%	40-50%	40-50%	40-50%	40-50%	40-50%	40-50%
50-60%	50-60%	50-60%	50-60%	50-60%	50-60%	50-60%	N/A	50-60%	50-60%	50-60%	50-60%	50-60%	50-60%	50-60%
60-70%	60-70%	60-70%	60-70%	60-70%	60-70%	60-70%	N/A	60-70%	60-70%	60-70%	60-70%	60-70%	60-70%	60-70%
70-80%	70-80%	70-80%	70-80%	70-80%	70-80%	70-80%	N/A	70-80%	70-80%	70-80%	70-80%	70-80%	70-80%	70-80%
2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	N/A	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000
500,000	500,000	500,000	500,000	500,000	500,000	500,000	N/A	500,000	500,000	500,000	500,000	500,000	500,000	500,000
100,000	100,000	100,000	100,000	100,000	100,000	100,000	N/A	100,000	100,000	100,000	100,000	100,000	100,000	100,000
45,000	45,000	45,000	45,000	45,000	45,000	45,000	N/A	45,000	45,000	45,000	45,000	45,000	45,000	45,000
20,000	20,000	20,000	20,000	20,000	20,000	20,000	N/A	20,000	20,000	20,000	20,000	20,000	20,000	20,000
14,000	14,000	14,000	14,000	14,000	14,000	14,000	N/A	14,000	14,000	14,000	14,000	14,000	14,000	14,000
10,000	10,000	10,000	10,000	10,000	10,000	10,000	N/A	10,000	10,000	10,000	10,000	10,000	10,000	10,000
8,000	8,000	8,000	8,000	8,000	8,000	8,000	N/A	8,000	8,000	8,000	8,000	8,000	8,000	8,000
4,000	4,000	4,000	4,000	4,000	4,000	4,000	N/A	4,000	4,000	4,000	4,000	4,000	4,000	4,000

Run #36	Run #37	Run #38	Run #39	Run #40	Run #41	Run #42	Run #44	Run #45	Run #46	Run #47	Run #48	Run #49	Units
Battery - 4h	Battery - 4h	Battery - 4h	Flow Battery	Battery - 2h	Battery - 2h	Battery - 2h	Flywheel	Flow Battery	Flywheel	Battery - Short Duration	Battery - 4h	Battery - 4h	
2020	2020	2020	2020	2020	2020	2020	2020	2015	2015	2015	2015	2015	
20	20	20	20	20	20	20	20	17	20	20	20	20	yr
1	0.500	0.500	1	0.250	0.250	0.250	20	50	20	20	0.500	0.500	MW
105	105	105	105	105	105	105	105	105	105	105	105	105	DegF
1	0.500	0.500	1	0.250	0.250	0.250	20	50	20	20	0.500	0.500	MW
4	4	4	4	2	2	2	0.25	4	0.25	0.25	4	4	h
1	0.500	0.500	1	0.250	0.250	0.250	20	50	20	20	0.500	0.500	MW
86	86	86	86	86	86	86	86	86	86	86	86	86	DegF
1	0.500	0.500	1	0.250	0.250	0.250	20	50	20	20	0.500	0.500	MW
													Units
83%	83%	83%	75%	83%	83%	83%	84%	70%	84%	83%	83%	83%	Btu/kWh HHV or %
86	86	86	86	86	86	86	86	86	86	86	86	86	DegF
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	% of optimal efficiency
20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	%
30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	%
85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	%
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	%
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	% of optimal efficiency
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	% of optimal efficiency
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	% of optimal efficiency
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	% of optimal efficiency
2.00%	2.00%	2.00%	0.00%	2.00%	2.00%	2.00%	0.00%	0.00%	0.00%	2.00%	2.00%	2.00%	%/yr
													Units
$1,750	$1,750	$1,750	$2,850	$1,050	$1,050	$1,050	$1,538	$2,022	$1,788	$1,028	$2,000	$2,000	$/kW
													Units

$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$0.2500	$0.0000	$0.2500	$0.0000	$0.2500	$0.2500	$0.2500	$/MWh
$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$43.00	$15.00	$43.00	$15.00	$15.00	$15.00	$/kW-yr
$250	$250	$250	$0	$250	$250	$250	$0	$0	$0	$250	$250	$250	$/kWh
2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	%/yr

N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Unitless
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	MMBtu/MW
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$/Start
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	% of Discharge Capacit
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	%
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	% of Charge Capacity
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	% of Discharge Capacit
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	%
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	%
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Yes/No

													Units
0-3%	0-3%	0-3%	N/A	0-3%	0-3%	0-3%	N/A	N/A	N/A	0-3%	0-3%	0-3%	%
3-10%	3-10%	3-10%	N/A	3-10%	3-10%	3-10%	N/A	N/A	N/A	3-10%	3-10%	3-10%	%
10-20%	10-20%	10-20%	N/A	10-20%	10-20%	10-20%	N/A	N/A	N/A	10-20%	10-20%	10-20%	%
20-30%	20-30%	20-30%	N/A	20-30%	20-30%	20-30%	N/A	N/A	N/A	20-30%	20-30%	20-30%	%
30-40%	30-40%	30-40%	N/A	30-40%	30-40%	30-40%	N/A	N/A	N/A	30-40%	30-40%	30-40%	%
40-50%	40-50%	40-50%	N/A	40-50%	40-50%	40-50%	N/A	N/A	N/A	40-50%	40-50%	40-50%	%
50-60%	50-60%	50-60%	N/A	50-60%	50-60%	50-60%	N/A	N/A	N/A	50-60%	50-60%	50-60%	%
60-70%	60-70%	60-70%	N/A	60-70%	60-70%	60-70%	N/A	N/A	N/A	60-70%	60-70%	60-70%	%
70-80%	70-80%	70-80%	N/A	70-80%	70-80%	70-80%	N/A	N/A	N/A	70-80%	70-80%	70-80%	%
2,000,000	2,000,000	2,000,000	N/A	2,000,000	2,000,000	2,000,000	N/A	N/A	N/A	2,000,000	2,000,000	2,000,000	Unitless
500,000	500,000	500,000	N/A	500,000	500,000	500,000	N/A	N/A	N/A	500,000	500,000	500,000	Unitless
100,000	100,000	100,000	N/A	100,000	100,000	100,000	N/A	N/A	N/A	100,000	100,000	100,000	Unitless
45,000	45,000	45,000	N/A	45,000	45,000	45,000	N/A	N/A	N/A	45,000	45,000	45,000	Unitless
20,000	20,000	20,000	N/A	20,000	20,000	20,000	N/A	N/A	N/A	20,000	20,000	20,000	Unitless
14,000	14,000	14,000	N/A	14,000	14,000	14,000	N/A	N/A	N/A	14,000	14,000	14,000	Unitless
10,000	10,000	10,000	N/A	10,000	10,000	10,000	N/A	N/A	N/A	10,000	10,000	10,000	Unitless
8,000	8,000	8,000	N/A	8,000	8,000	8,000	N/A	N/A	N/A	8,000	8,000	8,000	Unitless
4,000	4,000	4,000	N/A	4,000	4,000	4,000	N/A	N/A	N/A	4,000	4,000	4,000	Unitless

Applicable Technologies	Source	Notes
All		*Technology that assumptions are based on*
All		*Year project is online and align with specs and costs*
All		*Useful/planned operational life*
All		*Nameplate discharge capacity*
All		*Temperature selected to specify derated capacity #4*
All		*Derated capacity at temperature #4*
All Storage		*Discharge duration at nameplate capacity*
All Storage		*Nameplate charge capacity*
All Storage		*Temperature selected to specify derated capacity #4*
All Storage		*Derated capacity at temperature #4*

Applicable Technologies	Source	Notes
All		*Efficiency at optimal load, temperature, and ramp*
All Except Pumped Storage		*Temperature selected to specify derated efficiency #4*
All Except Pumped Storage		*Derated efficiency at temperature #4*
All Except Pumped Storage		*Percent of full load selected to specify derated efficiency #1*
All Except Pumped Storage		*Percent of full load selected to specify derated efficiency #2*
All Except Pumped Storage		*Percent of full load selected to specify derated efficiency #3*
All Except Pumped Storage		*Percent of full load selected to specify derated efficiency #4*
All Except Pumped Storage		*Derated efficiency at percent of full load #1*
All Except Pumped Storage		*Derated efficiency at percent of full load #2*
All Except Pumped Storage		*Derated efficiency at percent of full load #3*
All Except Pumped Storage		*Derated efficiency at percent of full load #4*
All Storage		*Annual duration degradation*

Applicable Technologies	Source	Notes
All		*Calculated*

Applicable Technologies	Source	Notes

All	*Consumables such as water supply costs, etc.; excludes fuel costs*
All	*Labor, etc.*
Storage Only	*Based on nominal energy capacity*
Storage Only	*Annual reduction in major overhaul costs, which is subtracted from the general inflation rate in ESVT*
CAES	*Electrical efficiency of CAES facility (>1)*
CAES/CT	*Fuel use per start-up*
Pumped Storage	*Costs associated with startup of pumped storage turbine*
CAES/CT	*Pmin of turbine*
CAES	*Efficiency of compression cycle*
Pumped Storage	*Pmin of pump*
Pumped Storage	*Pmin of turbine*
Pumped Storage	*Pumped storage pump efficiency*
Pumped Storage	*Pumped storage turbine efficiency*
CAES	*Determines whether CAES can support bids both from compression and generation side of facility within the*

Applicable Technologies	Source	Notes
Battery & Flow Battery		
Battery & Flow Battery		
Battery & Flow Battery		
Battery & Flow Battery		
Battery & Flow Battery		
Battery & Flow Battery		
Battery & Flow Battery		
Battery & Flow Battery		
Battery & Flow Battery		
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Battery & Flow Battery		
Battery & Flow Battery		
Battery & Flow Battery		
Battery & Flow Battery		

EXHIBIT 16

BILL POWERS, P.E.

PROFESSIONAL HISTORY

Powers Engineering, San Diego, CA 1994-
ENSR Consulting and Engineering, Camarillo, CA 1989-93
Naval Energy and Environmental Support Activity, Port Hueneme, CA 1982-87
U.S. Environmental Protection Agency, Research Triangle Park, NC 1980-81

EDUCATION

Master of Public Health – Environmental Sciences, University of North Carolina
Bachelor of Science – Mechanical Engineering, Duke University

PROFESSIONAL AFFILIATIONS

Registered Professional Mechanical Engineer, California (Certificate M24518)
American Society of Mechanical Engineers
Air & Waste Management Association

TECHNICAL SPECIALTIES

Thirty years of experience in:

- Power plant air emission control system and cooling system assessments
- Petroleum refinery air engineering and testing
- Combustion equipment permitting, testing and monitoring
- Air pollution control equipment retrofit design/performance testing
- Distributed solar photovoltaics (PV) siting and regional renewable energy planning
- Latin America environmental project experience

POWER PLANT EMISSION CONTROL AND COOLING SYSTEM CONVERSION ASSESSMENTS

LMS100 Gas Turbine Power Plant Air Emissions Control Assessment. Lead engineer to assess Best Available Control Technology (BACT) for four proposed LMS100 gas turbines to be owned and operated by El Paso Electric Company. El Paso Electric proposed NOx and CO emission rates of 2.5 ppm and 6.0 ppm respectively, use of wet cooling tower(s) for intercooler heat rejection, and up to 5,000 hours per year of operation. I identified BACT as equivalent to combined cycle plant levels, 2.0 ppm NO_x and 2.0 ppm CO, due to high operating hour limit., and air cooling with mist augmentation at high ambient temperatures as BACT for PM. The TCEQ Office of Public Interest Council agreed that BACT for the LMS100s should be 2.0 ppm NO_x and 2.0 ppm CO, and that air cooling with mist augmentation should be BACT for PM.

Biomass Plant NO_x and CO Air Emissions Control Evaluation. Lead engineer for evaluation of available nitrogen oxide (NO_x) and carbon monoxide (CO) controls for a 45 MW Aspen Power biomass plant in Texas where proponent had identified selective non-catalytic reduction (SNCR) for NO_x and good combustion practices for CO as BACT. Identified the use of tail-end SCR for NO_x control at several operational U.S. biomass plants, and oxidation catalyst in use at two of these plants for CO and VOC control, as BACT for the proposed biomass plant. Administrative law judge concurred in decision that SCR and oxidation catalyst is BACT. Developer added SCR and oxidation catalyst to project in subsequent settlement agreement.

Biomass Plant Air Emissions Control Consulting. Lead expert on biomass air emissions control systems for landowners that will be impacted by a proposed 50 MW biomass to be built by the local East Texas power cooperative. Public utility agreed to meet current BACT for biomass plants in Texas, SCR for NOx and oxidation catalyst for CO, in settlement agreement with local landowners.

Combined-Cycle Power Plant Startup and Shutdown Emissions. Lead engineer for analysis of air permit startup and shutdown emissions minimization for combined-cycle power plant proposed for the San Francisco Bay Area. Original equipment was specified for baseload operation prior to suspension of project in early 2000s. Operational profile described in revised air permit was load following with potential for daily start/stop. Recommended that either fast start turbine technology be employed to minimize start/stop emissions or that "demonstrated in practice" operational and control software modifications be employed to minimize startup/shutdown emissions.

IGCC as BACT for Air Emissions from Proposed 960 MW Coal Plant. Presented testimony on IGCC as BACT for air emissions reduction from 960 MW coal plant. Applicant received air permit for a pulverized coal plant to be equipped with a baghouse, wet scrubber, and wet ESP for air emissions control. Use of IGCC technology at the emission rates permitted for two recently proposed U.S. IGCC projects, and demonstrated in practice at a Japanese IGCC plant firing Chinese bituminous coal, would substantially reduce potential emissions of NO_x, SO_2, and PM. The estimated control cost-effectiveness of substituting IGCC for pulverized coal technology in this case was approximately $3,000/ton.

Analysis of Proposed Air Emission Limits for 600 MW Pulverized Coal Plant. Project engineer tasked with evaluating sufficiency of air emissions limits and control technologies for proposed 600 MW coal plant Arkansas. Determined that the applicant had: 1) not properly identified SO_2, sulfuric acid mist, and PM BACT control levels for the plant, and 2) improperly utilized an incremental cost effectiveness analysis to justify air emission control levels that did not represent BACT.

Eight Pulverized Coal Fired 900 MW Boilers – IGCC Alternative with Air Cooling. Provided testimony on integrated gasification combined cycle (IGCC) as a fully commercial coal-burning alternative to the pulverized coal (PC) technology proposed by TXU for eight 900 MW boilers in East Texas, and East Texas as an ideal location for CO2 sequestration due to presence of mature oilfield CO2 enhanced oil recovery opportunities and a deep saline aquifer underlying the entire region. Also presented testimony on the major increase in regional consumptive water use that would be caused by the evaporative cooling towers proposed for use in the PC plants, and that consumptive water use could be lowered by using IGCC with evaporative cooling towers or by using air-cooled condensers with PC or IGCC technology. TXU ultimately dropped plans to build the eight PC plants as a condition of a corporate buy-out.

Utility Boilers – Conversion of Existing Once-Through Cooled Boilers to Wet Towers, Parallel Wet-Dry Cooling, or Dry Cooling. Provided expert testimony and preliminary design for the conversion of four natural gas and/or coal-fired utility boilers (Unit 4, 235 MW; Unit 3, 135 MW; Unit 2, 65 MW; and Unit 1,65 MW) from once-through river water cooling to wet cooling towers, parallel wet-dry cooling, and dry cooling. Major design constraints were available land for location of retrofit cooling systems and need to maintain maximum steam turbine backpressure at or below 5.5 inches mercury to match performance capabilities of existing equipment. Approach temperatures of 12 °F and 13 °F were used for the wet towers. SPX Cooling Technologies F-488 plume-abated wet cells with six feet of packing were used to achieve approach temperatures of 12 °F and 13 °F. Annual energy penalty of wet tower retrofit designs is approximately 1 percent. Parallel wet-dry or dry cooling was determined to be technically feasible for Unit 3 based on straightforward access to the Unit 3 surface condenser and available land adjacent to the boiler.

Utility Boiler – Assessment of Air Cooling and Integrated Gasification/Combined Cycle for Proposed 500 MW Coal-Fired Plant. Provided expert testimony on the performance of air-cooling and IGCC relative to the conventional closed-cycle wet cooled, supercritical pulverized coal boiler proposed by the applicant. Steam Pro™ coal-fired power plant design software was used to model the proposed plant and evaluate the impacts on performance of air cooling and plume-abated wet cooling. Results indicated that a conservatively designed air-cooled condenser could maintain rated power output at the design ambient temperature of 90 °F. The IGCC comparative analysis indicated that unit reliability comparable to a conventional pulverized coal unit could be achieved by including a spare gasifier in the IGCC design, and that the slightly higher capital cost of IGCC was offset by greater thermal efficiency and reduced water demand and air emissions.

Utility Boiler – Assessment of Closed-Cycle Cooling Retrofit Cost for 1,200 MW Oil-Fired Plant. Prepared an assessment of the cost and feasibility of a closed-cycle wet tower retrofit for the 1,200 MW Roseton Generating Station. Determined that the cost to retrofit the Roseton plant with plume-abated closed-cycle wet cooling was well established based on cooling tower retrofit studies performed by the original owner (Central Hudson Gas & Electric Corp.) and subsequent regulatory agency critique of the cost estimate. Also determined that elimination of redundant and/or excessive budgetary line items in owners cost estimate brings the closed-cycle retrofit in line with expected costs for comparable new or retrofit plume-abated cooling tower applications.

Nuclear Power Plant – Assessment of Closed-Cycle Cooling Retrofit Cost for 2,000 MW Plant. Prepared an assessment of the cost and feasibility of a closed-cycle wet tower retrofit for the 2,000 MW Indian Point Generating Station. Determined that the most appropriate arrangement for the hilly site would be an inline plume-abated wet tower instead of the round tower configuration analyzed by the owner. Use of the inline configuration would allow placement of the towers at numerous sites on the property with little or need for blasting of bedrock, greatly reducing the cost of the retrofit. Also proposed an alternative circulating cooling water piping configuration to avoid the extensive downtime projected by the owner for modifications to the existing discharge channel.

Kentucky Coal-Fired Power Plant – Pulverized Coal vs IGCC. Expert witness in Sierra Club lawsuit against Peabody Coal Company's plan to construct a 1,500 MW pulverized-coal fired power plant in Kentucky. Presented case that Integrated Gasification Combined Cycle (IGCC) is a superior method for producing power from coal, from environmental and energy efficiency perspective, than the proposed pulverized-coal plant. Presented evidence that IGCC is technically feasible and cost competitive with pulverized coal.

Power Plant Dry Cooling Symposium – Chair and Organizer. Chair and organizer of the first symposium held in the U.S. (May 2002) that focused exclusively on dry cooling technology for power plants. Sessions included basic principles of wet and dry cooling systems, performance capabilities of dry cooling systems, case studies of specific installations, and reasons why dry cooling is the predominant form of cooling specified in certain regions of North America (Massachusetts, Nevada, northern Mexico).

Utility Boiler Best Available NO_x Control System for 525 MW Coal-Fired Circulating Fluidized Bed Boiler Plant. Expert witness in dispute over whether 50 percent NO_x control using selective non-catalytic reduction (SNCR) constituted BACT for a proposed 525 MW circulating fluidized bed (CFB) boiler plant. Presented testimony that SNCR was capable of continuous NO_x reduction of greater than 70 percent on a CFB unit and that tail-end selective catalytic reduction (SCR) was technically feasible and could achieve greater than 90 percent NO_x reduction.

Utility Boilers – Evaluation of Correlation Between Opacity and PM_{10} Emissions at Coal-Fired Plant. Provided expert testimony on whether correlation existed between mass PM_{10} emissions and opacity during opacity excursions at large coal-fired boiler in Georgia. EPA and EPRI technical studies were reviewed to assess the correlation of opacity and mass emissions during opacity levels below and above 20 percent. A strong correlation between opacity and mass emissions was apparent at a sister plant at opacities less than 20 percent. The correlation suggests that the opacity monitor correlation underestimates mass emissions at opacities greater than 20 percent, but may continue to exhibit a good correlation for the component of mass emissions in the PM_{10} size range.

Utility Boilers Retrofit of SCR and FGD to Existing Coal-Fired Units.
Expert witness in successful effort to compel an existing coal-fired power plant located in Massachusetts to meet an accelerated NO_x and SO_2 emission control system retrofit schedule. Plant owner argued the installation of advanced NO_x and SO_2 control systems would generate > 1 ton/year of ancillary emissions, such as sulfuric acid mist, and that under Massachusetts Dept. of Environmental Protection regulation ancillary emissions > 1 ton/year would require a BACT evaluation and a two-year extension to retrofit schedule. Successfully demonstrated that no ancillary emissions would be generated if the retrofit NO_x and SO_2 control systems were properly sized and optimized. Plant owner committed to accelerated compliance schedule in settlement agreement.

Utility Boilers – Retrofit of SCR to Existing Natural Gas-Fired Units.
Lead engineer in successful representation of interests of California coastal city to prevent weakening of an existing countywide utility boiler NO_x rule. Weakening of NO_x rule would have allowed a merchant utility boiler plant located in the city to operate without installing selective catalytic reduction (SCR) NO_x control systems. This project required numerous appearances before the county air pollution control hearing board to successfully defend the existing utility boiler NO_x rule.

PETROLEUM REFINERY AIR ENGINEERING/TESTING EXPERIENCE

BP Whiting Refinery Expansion Air Permit. Served as lead engineer on review of netting analysis that resulted in the BP Whiting Refinery Expansion receiving a minor source air permit from the Indiana Department of Environmental Management. Determined that BP Whiting omitted several major sources of emissions, underestimated others, and incorrectly calculated contemporaneous increases and decreases in air emissions. These sources included refinery heaters, flares, coking units, sulfur recovery, and fugitive emissions. These errors and omissions were sufficient in number and magnitude to exceed NSR significance thresholds.

Hyperion Refinery Air Permit. Served as lead engineer on review of BACT determinations in the PSD air permit for the proposed Hyperion Refinery in South Dakota.. BACT review included controls for refinery heaters, cooling systems, fugitive emissions, and greenhouse gases. BACT was identified as SCR for all refinery heaters, use of enclosed ground flare for periodic flare gas emissions from gasification process, and use of leakless fugitive emission components.

Big West Refinery Expansion EIS. Lead engineer on comparative cost analysis of proposed wet cooling tower and fin-fan air cooler for process cooling water for the proposed clean fuels expansion project at the Big West Refinery in Bakersfield, California. Selection of the fin-fin air-cooler would eliminate all consumptive water use and wastewater disposal associated with the cooling tower. Air emissions of VOC and PM_{10} would be reduced with the fin-fan air-cooler even though power demand of the air-cooler is incrementally higher than that of the cooling tower. Fin-fan air-coolers with approach temperatures of 10 °F and 20 °F were evaluated. The annualized cost of the fin-fin air-cooler with a 20 °F approach temperature is essentially the same as that of the cooling tower when the cost of all ancillary cooling tower systems are considered.

Criteria and Air Toxic Pollutant Emissions Inventory for Proposed Refinery Modifications. Project manager and technical lead for development of baseline and future refinery air emissions inventories for process modifications required to produce oxygenated gasoline and desulfurized diesel fuel at a California refinery. State of the art criteria and air toxic pollutant emissions inventories for refinery point, fugitive and mobile sources were developed. Point source emissions estimates were generated using onsite criteria pollutant test data, onsite air toxics test data, and the latest air toxics emission factors from the statewide refinery air toxics inventory database. The fugitive volatile organic compound (VOC) emissions inventories were developed using the refinery's most recent inspection and maintenance (I&M) monitoring program test data to develop site-specific component VOC emission rates. These VOC emission rates were combined with speciated air toxics test results for the principal refinery process streams to produce fugitive VOC air toxics emission rates. The environmental impact report (EIR) that utilized this emission inventory data was the first refinery "Clean Fuels" EIR approved in California.

Development of Air Emission Standards for Petroleum Refinery Equipment - Peru. Served as principal technical consultant to the Peruvian Ministry of Energy in Mines (MEM) for the development of air emission standards for Peruvian petroleum refineries. The sources included in the scope of this project included: 1) SO_2 and NO_x refinery heaters and boilers, 2) desulfurization of crude oil, particulate and SO_2 controls for fluid catalytic cracking units (FCCU), 3) VOC and CO emissions from flares, 4) vapor recovery systems for marine unloading, truck loading, and crude oil/refined products storage tanks, and 5) VOC emissions from process fugitive sources such as pressure relief valves, pumps, compressors and flanges. Proposed emission limits were developed for new and existing refineries based on a thorough evaluation of the available air emission control technologies for the affected refinery sources. Leading vendors of refinery control technology, such as John Zink and Exxon Research, provided estimates of retrofit costs for the largest Peruvian refinery, La Pampilla, located in Lima. Meetings were held in Lima with refinery operators and MEM staff to discuss the proposed emission limits and incorporate mutually agreed upon revisions to the proposed limits for existing Peruvian refineries.

Air Toxic Pollutant Emissions Inventory for Existing Refinery. Project manager and technical lead for air toxic pollutant emissions inventory at major California refinery. Emission factors were developed for refinery heaters, boilers, flares, sulfur recovery units, coker deheading, IC engines, storage tanks, process fugitives, and catalyst regeneration units. Onsite source test results were utilized to characterize emissions from refinery combustion devices. Where representative source test results were not available, AP-42 VOC emission factors were combined with available VOC air toxics speciation profiles to estimate VOC air toxic emission rates. A risk assessment based on this emissions inventory indicated a relatively low health risk associated with refinery operations. Benzene, 1,3-butadiene and PAHs were the principal health risk related pollutants emitted.

Air Toxics Testing of Refinery Combustion Sources. Project manager for comprehensive air toxics testing program at a major California refinery. Metals, Cr^{+6}, PAHs, H_2S and speciated VOC emissions were measured from refinery combustion sources. High temperature Cr^{+6} stack testing using the EPA Cr^{+6} test method was performed for the first time in California during this test program. Representatives from the California Air Resources Board source test team performed simultaneous testing using ARB Method 425 (Cr^{+6}) to compare the results of EPA and ARB Cr^{+6} test methodologies. The ARB approved the test results generated using the high temperature EPA Cr^{+6} test method.

Air Toxics Testing of Refinery Fugitive Sources. Project manager for test program to characterize air toxic fugitive VOC emissions from fifteen distinct process units at major California refinery. Gas, light liquid, and heavy liquid process streams were sampled. BTXE, 1,3-butadiene and propylene concentrations were quantified in gas samples, while BTXE, cresol and phenol concentrations were measured in liquid samples. Test results were combined with AP-42 fugitive VOC emission factors for valves, fittings, compressors, pumps and PRVs to calculate fugitive air toxics VOC emission rates.

COMBUSTION EQUIPMENT PERMITTING, TESTING AND MONITORING

EPRI Gas Turbine Power Plant Permitting Documents – Co-Author.
Co-authored two Electric Power Research Institute (EPRI) gas turbine power plant siting documents. Responsibilities included chapter on state-of-the-art air emission control systems for simple-cycle and combined-cycle gas turbines, and authorship of sections on dry cooling and zero liquid discharge systems.

Air Permits for 50 MW Peaker Gas Turbines – Six Sites Throughout California.
Responsible for preparing all aspects of air permit applications for five 50 MW FT-8 simple-cycle turbine installations at sites around California in response to emergency request by California state government for additional peaking power. Units were designed to meet 2.0 ppm NO_x using standard temperature SCR and innovative dilution air system to maintain exhaust gas temperature within acceptable SCR range.

Oxidation catalyst is also used to maintain CO below 6.0 ppm.

Kauai 27 MW Cogeneration Plant – Air Emission Control System Analysis. Project manager to evaluate technical feasibility of SCR for 27 MW naphtha-fired turbine with once-through heat recovery steam generator. Permit action was stalled due to questions of SCR feasibility. Extensive analysis of the performance of existing oil-fired turbines equipped with SCR, and bench-scale tests of SCR applied to naphtha-fired turbines, indicated that SCR would perform adequately. Urea was selected as the SCR reagent given the wide availability of urea on the island. Unit is first known application of urea-injected SCR on a naphtha-fired turbine.

Microturbines Ronald Reagan Library, Ventura County, California.
Project manager and lead engineer or preparation of air permit applications for microturbines and standby boilers. The microturbines drive the heating and cooling system for the library. The microturbines are certified by the manufacturer to meet the 9 ppm NO_x emission limit for this equipment. Low-NO_x burners are BACT for the standby boilers.

Hospital Cogeneration Microturbines – South Coast Air Quality Management District.
Project manager and lead engineer for preparation of air permit application for three microturbines at hospital cogeneration plant installation. The draft Authority To Construct (ATC) for this project was obtained two weeks after submittal of the ATC application. 30-day public notification was required due to the proximity of the facility to nearby schools. The final ATC was issued two months after the application was submitted, including the 30-day public notification period.

Gas Turbine Cogeneration – South Coast Air Quality Management District. Project manager and lead engineer for preparation of air permit application for two 5.5 MW gas turbines in cogeneration configuration for county government center. The turbines will be equipped with selective catalytic reduction (SCR) and oxidation catalyst to comply with SCAQMD BACT requirements. Aqueous urea will be used as the SCR reagent to avoid trigger hazardous material storage requirements. A separate permit will be obtained for the NO_x and CO continuous emissions monitoring systems. The ATCs is pending.

Industrial Boilers NO_x BACT Evaluation for San Diego County Boilers.
Project manager and lead engineer for preparation of Best Available Control Technology (BACT) evaluation for three industrial boilers to be located in San Diego County. The BACT included the review of low NO_x burners, FGR, SCR, and low temperature oxidation (LTO). State-of-the-art ultra low NO_x burners with a 9 ppm emissions guarantee were selected as NO_x BACT for these units.

Peaker Gas Turbines – Evaluation of NO_x Control Options for Installations in San Diego County.
Lead engineer for evaluation of NO_x control options available for 1970s vintage simple-cycle gas turbines proposed for peaker sites in San Diego County. Dry low-NO_x (DLN) combustors, catalytic combustors, high-temperature SCR, and NO_x absorption/conversion ($SCONO_x$) were evaluated for each candidate turbine make/model. High-temperature SCR was selected as the NOx control option to meet a 5 ppm NO_x emission requirement.

Hospital Cogeneration Plant Gas Turbines – San Joaquin Valley Unified Air Pollution Control District.
Project manager and lead engineer for preparation of air permit application and Best Available Control Technology (BACT) evaluation for hospital cogeneration plant installation. The BACT included the review of DLN combustors, catalytic combustors, high-temperature SCR and $SCONO_x$. DLN combustion followed by high temperature SCR was selected as the NO_x control system for this installation. The high temperature SCR is located upstream of the heat recovery steam generator (HRSG) to allow the diversion of exhaust gas around the HRSG without compromising the effectiveness of the NO_x control system.

1,000 MW Coastal Combined-Cycle Power Plant – Feasibility of Dry Cooling.
Expert witness in on-going effort to require use of dry cooling on proposed 1,000 MW combined-cycle "repower" project at site of an existing 1,000 MW utility boiler plant. Project proponent argued that site was

two small for properly sized air-cooled condenser (ACC) and that use of ACC would cause 12-month construction delay. Demonstrated that ACC could easily be located on the site by splitting total of up to 80 cells between two available locations at the site. Also demonstrated that an ACC optimized for low height and low noise would minimize or eliminate proponent claims of negative visual and noise impacts.

Industrial Cogeneration Plant Gas Turbines Upgrade of Turbine Power Output.
Project manager and lead engineer for preparation of Best Available Control Technology (BACT) evaluation for proposed gas turbine upgrade. The BACT included the review of DLN combustors, catalytic combustors, high-, standard-, and low-temperature SCR, and $SCONO_x$. Successfully negotiated air permit that allowed facility to initially install DLN combustors and operate under a NO_x plantwide "cap." Within two major turbine overhauls, or approximately eight years, the NO_x emissions per turbine must be at or below the equivalent of 5 ppm. The 5 ppm NO_x target will be achieved through technological in-combustor NO_x control such as catalytic combustion, or SCR or SCR equivalent end-of-pipe NO_x control technologies if catalytic combustion is not available.

Gas Turbines Modification of RATA Procedures for Time-Share CEM.
Project manager and lead engineer for the development of alternate CO continuous emission monitor (CEM) Relative Accuracy Test Audit (RATA) procedures for time-share CEM system serving three 7.9 MW turbines located in San Diego. Close interaction with San Diego APCD and EPA Region 9 engineers was required to receive approval for the alternate CO RATA standard. The time-share CEM passed the subsequent annual RATA without problems as a result of changes to some of the CEM hardware and the more flexible CO RATA standard.

Gas Turbines Evaluation of NO_x Control Technology Performance. Lead engineer for performance review of dry low-NO_x combustors, catalytic combustors, high-, standard-, and low-temperature selective catalytic reduction (SCR), and NO_x absorption/conversion ($SCONO_x$). Major turbine manufacturers and major manufacturers of end-of-pipe NO_x control systems for gas turbines were contacted to determine current cost and performance of NO_x control systems. A comparison of 1993 to 1999 "$/kwh" and "$/ton" cost of these control systems was developed in the evaluation.

Gas Turbines Evaluation of Proposed NO_x Control System to Achieve 3 ppm Limit.
Lead engineer for evaluation for proposed combined cycle gas turbine NO_x and CO control systems. Project was in litigation over contract terms, and there was concern that the GE Frame 7FA turbine could not meet the 3 ppm NO_x permit limit using a conventional combustor with water injection followed by SCR. Operations personnel at GE Frame 7FA installatins around the country were interviewed, along with principal SCR vendors, to corroborate that the installation could continuously meet the 3 ppm NO_x limit.

Gas Turbines Title V "Presumptively Approvable" Compliance Assurance Monitoring Protocol.
Project manager and lead engineer for the development of a "presumptively approval" NO_x parametric emissions monitoring system (PEMS) protocol for industrial gas turbines. "Presumptively approvable" means that any gas turbine operator selecting this monitoring protocol can presume it is acceptable to the U.S. EPA. Close interaction with the gas turbine manufacturer's design engineering staff and the U.S. EPA Emissions Measurement Branch (Research Triangle Park, NC) was required to determine modifications necessary to the current PEMS to upgrade it to "presumptively approvable" status.

Environmental Due Diligence Review of Gas Turbine Sites Mexico. Task leader to prepare regulatory compliance due diligence review of Mexican requirements for gas turbine power plants. Project involves eleven potential sites across Mexico, three of which are under construction. Scope involves identification of all environmental, energy sales, land use, and transportation corridor requirements for power projects in Mexico. Coordinator of Mexican environmental subcontractors gathering on-site information for each site, and translator of Spanish supporting documentation to English.

Development of Air Emission Standards for Gas Turbines - Peru. Served as principal technical consultant to the Peruvian Ministry of Energy in Mines (MEM) for the development of air emission standards for Peruvian gas turbine power plants. All major gas turbine power plants in Peru are currently using water injection to increase turbine power output. Recommended that 42 ppm on natural gas and 65 ppm on diesel (corrected to 15% O_2) be established as the NO_x limit for existing gas turbine power plants. These limits reflect NO_x levels readily achievable using water injection at high load. Also recommended that new gas turbine sources be subject to a BACT review requirement.

Gas Turbines □ Title V Permit Templates. Lead engineer for the development of standardized permit templates for approximately 100 gas turbines operated by the oil and gas industry in the San Joaquin Valley. Emissions limits and monitoring requirements were defined for units ranging from GE Frame 7 to Solar Saturn turbines. Stand-alone templates were developed based on turbine size and NO_x control equipment. NO_x utilized in the target turbine population ranged from water injection alone to water injection combined with SCR.

Gas Turbines □ Evaluation of NO_x, SO_2 and PM Emission Profiles. Performed a comparative evaluation of the NO_x, SO_2 and particulate (PM) emission profiles of principal utility-scale gas turbines for an independent power producer evaluating project opportunities in Latin America. All gas turbine models in the 40 MW to 240 MW range manufactured by General Electric, Westinghouse, Siemens and ABB were included in the evaluation.

Stationary Internal Combustion Engine (ICE) RACT/BARCT Evaluation. Lead engineer for evaluation of retrofit NO_x control options available for the oil and gas production industry gas-fired ICE population in the San Joaquin Valley affected by proposed RACT and BARCT emission limits. Evaluation centered on lean-burn compressor engines under 500 bhp, and rich-burn constant and cyclically loaded (rod pump) engines under 200 bhp. The results of the evaluation indicated that rich burn cyclically-loaded rod pump engines comprised 50 percent of the affected ICE population, though these ICEs accounted for only 5 percent of the uncontrolled gas-fired stationary ICE NO_x emissions. Recommended retrofit NO_x control strategies included: air/fuel ratio adjustment for rod pump ICEs, Non-selective catalytic reduction (NSCR) for rich-burn, constant load ICEs, and "low emission" combustion modifications for lean burn ICEs.

Development of Air Emission Standards for Stationary ICEs - Peru. Served as principal technical consultant to the Peruvian Ministry of Energy in Mines (MEM) for the development of air emission standards for Peruvian stationary ICE power plants. Draft 1997 World Bank NO_x and particulate emission limits for stationary ICE power plants served as the basis for proposed MEM emission limits. A detailed review of ICE emissions data provided in PAMAs submitted to the MEM was performed to determine the level of effort that would be required by Peruvian industry to meet the proposed NO_x and particulate emission limits. The draft 1997 WB emission limits were revised to reflect reasonably achievable NO_x and particulate emission limits for ICEs currently in operation in Peru.

Air Toxics Testing of Natural Gas-Fired ICEs. Project manager for test plan/test program to measure volatile and semi-volatile organic air toxics compounds from fourteen gas-fired ICEs used in a variety of oil and gas production applications. Test data was utilized by oil and gas production facility owners throughout California to develop accurate ICE air toxics emission inventories.

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AIR ENGINEERING/AIR TESTING PROJECT EXPERIENCE □ GENERAL

Reverse Air Fabric Filter Retrofit Evaluation □ Coal-Fired Boiler. Lead engineer for upgrade of reverse air fabric filters serving coal-fired industrial boilers. Fluorescent dye injected to pinpoint broken bags and damper leaks. Corrosion of pneumatic actuators serving reverse air valves and inadequate insulation identified as principal causes of degraded performance.

Pulse-Jet Fabric Filter Performance Evaluation Gold Mine. Lead engineer on upgrade of pulse-jet fabric filter and associated exhaust ventilation system serving an ore-crushing facility at a gold mine. Fluorescent dye used to identify bag collar leaks, and modifications were made to pulse air cycle time and duration. This marginal source was in compliance at 20 percent of emission limit following completion of repair work.

Pulse-Jet Fabric Filter Retrofit - Gypsum Calciner. Lead engineer on upgrade of pulse-jet fabric filter controlling particulate emissions from a gypsum calciner. Recommendations included a modified bag clamping mechanism, modified hopper evacuation valve assembly, and changes to pulse air cycle time and pulse duration.

Wet Scrubber Retrofit Plating Shop. Project engineer on retrofit evaluation of plating shop packed-bed wet scrubbers failing to meet performance guarantees during acceptance trials, due to excessive mist carryover. Recommendations included relocation of the mist eliminator (ME), substitution of the original chevron blade ME with a mesh pad ME, and use of higher density packing material to improve exhaust gas distribution. Wet scrubbers passed acceptance trials following completion of recommended modifications.

Electrostatic Precipitator (ESP) Retrofit Evaluation MSW Boiler. Lead engineer for retrofit evaluation of single field ESP on a municipal solid waste (MSW) boiler. Recommendations included addition of automated power controller, inlet duct turning vanes, and improved collecting plate rapping system.

ESP Electric Coil Rapper Vibration Analysis Testing - Coal-Fired Boiler. Lead engineer for evaluation of ESP rapper effectiveness test program on three field ESP equipped with "magnetically induced gravity return" (MIGR) rappers. Accelerometers were placed in a grid pattern on ESP collecting plates to determine maximum instantaneous plate acceleration at a variety of rapper power setpoints. Testing showed that the rappers met performance specification requirements.

Aluminum Remelt Furnace Particulate Emissions Testing. Project manager and lead engineer for high temperature (1,600 °F) particulate sampling of a natural gas-fired remelt furnace at a major aluminum rolling mill. Objectives of test program were to: 1) determine if condensable particulate was present in stack gases, and 2) to validate the accuracy of the in-stack continuous opacity monitor (COM). Designed and constructed a customized high temperature (inconel) PM_{10}/Mtd 17 sampling assembly for test program. An onsite natural gas-fired boiler was also tested to provide comparative data for the condensable particulate portion of the test program. Test results showed that no significant levels of condensable particulate in the remelt furnace exhaust gas, and indicated that the remelt furnace and boiler had similar particulate emission rates. Test results also showed that the COM was accurate.

Aluminum Remelt Furnace CO and NO_x Testing. Project manager and lead engineer for continuous week-long testing of CO and NO_x emissions from aluminum remelt furnace. Objective of test program was to characterize CO and NO_x emissions from representative remelt furnace for use in the facility's criteria pollution emissions inventory. A TECO Model 48 CO analyzer and a TECO Model 10 NO_x analyzer were utilized during the test program to provide $\pm$1 ppm measurement accuracy, and all test data was recorded by an automated data acquisition system.

DISTRIBUTED SOLAR PV SITING AND REGIONAL RENEWABLE ENERGY PLANNING

Bay Area Smart Energy 2020 Plan . Author of the March 2012 *Bay Area Smart Energy 2020* strategic energy plan for the nine-county region surrounding San Francisco Bay. This plan uses the zero net energy building targets in the *California Energy Efficiency Strategic Plan* as a framework to achieve a 60 percent reduction in GHG emissions from Bay Area electricity usage, and a 50 percent reduction in peak demand for grid electricity, by 2020. The 2020 targets in the plan include: 25 percent of detached homes and 20 percent of commercial buildings achieving zero net energy, adding 200 MW of community-scale microgrid battery storage and 400 MW of utility-scale battery storage, reduction in air conditioner loads by 50 percent through air conditioner cycling and targeted incentive funds to assure highest efficiency replacement units, and cooling system modifications to increase power output from The Geysers geothermal production zone in Sonoma County. Report is available online at: http://pacificenvironment.org/-1-87.

Solar PV technology selection and siting for SDG&E Solar San Diego project. Served as PV technology expert in California Public Utilities Commission proceeding to define PV technology and sites to be used in San Diego Gas & Electric (SDG&E) $250 million "Solar San Diego" project. Recommendations included: 1) prioritize use of roof-mounted thin-film PV arrays similar to the SCE urban PV program to maximize the installed PV capacity, 2) avoid tracking ground-mounted PV arrays due to high cost and relative lack of available land in the urban/suburban core, 3) and incorporate limited storage in fixed rooftop PV arrays to maximizing output during peak demand periods. Suitable land next to SDG&E substations capable of supporting 5 to 40 MW of PV (each) was also identified by Powers Engineering as a component of this project.

Rooftop PV alternative to natural gas-fired peaking gas turbines, Chula Vista. Served as PV technology expert in California Energy Commission (CEC) proceeding regarding the application of MMC Energy to build a 100 MW peaking gas turbine power plant in Chula Vista. Presented testimony that 100 MW of PV arrays in the Chula Vista area could provide the same level of electrical reliability on hot summer days as an equivalent amount of peaking gas turbine capacity at approximately the same cost of energy. The preliminary decision issued by the presiding CEC commissioner in the case recommended denial of the application in part due to failure of the applicant or CEC staff to thoroughly evaluate the PV alternative to the proposed turbines. No final decision has yet been issued in the proceeding (as of May 2009).

San Diego Smart Energy 2020 Plan. Author of October 2007 "San Diego Smart Energy 2020," an energy plan that focuses on meeting the San Diego region's electric energy needs through accelerated integration of renewable and non-renewable distributed generation, in the form of combined heat and power (CHP) systems and solar photovoltaic (PV) systems. PV would meet approximately 28 percent of the San Diego region's electric energy demand in 2020. Annual energy demand would drop 20 percent in 2020 relative to 2003 through use all cost-effective energy efficiency measures. Existing utility-scale gas-fired generation would continue to be utilized to provide power at night, during cloudy whether, and for grid reliability support. Report at: http://www.etechinternational.org/new_pdfs/smartenergy/52008_SmE2020_2nd.pdf

Development of San Diego Regional Energy Strategy 2030. Participant in the 18-month process in the 2002-2003 timeframe that led to the development of the San Diego Regional Energy Strategy 2030. This document was adopted by the SANDAG Board of Directors in July 2003 and defines strategic energy objectives for the San Diego region, including: 1) in-region power generation increase from 65% of peak demand in 2010 to 75% of peak demand in 2020, 2) 40% renewable power by 2030 with at least half of this power generated in-county, 3) reinforcement of transmission capacity as needed to achieve these objectives. The SANDAG Board of Directors voted unanimously on Nov. 17, 2006 to take no position on the Sunrise Powerlink proposal primarily because it conflicts the Regional Energy Strategy 2030 objective of increased in-region power generation. The Regional Energy Strategy 2030 is online at: http://www.energycenter.org/uploads/Regional_Energy_Strategy_Final_07_16_03.pdf

OIL AND GAS PRODUCTION AIR ENGINEERING/TESTING EXPERIENCE

Air Toxics Testing of Oil and Gas Production Sources. Project manager and lead engineer for test plan/test program to determine VOC removal efficiency of packed tower scrubber controlling sulfur dioxide emissions from a crude oil-fired steam generator. Ratfisch 55 VOC analyzers were used to measure the packed tower scrubber VOC removal efficiency. Tedlar bag samples were collected simultaneously to correlate BTX removal efficiency to VOC removal efficiency. This test was one of hundreds of air toxics tests performed during this test program for oil and gas production facilities from 1990 to 1992. The majority of the volatile air toxics analyses were performed at in-house laboratory. Project staff developed thorough familiarity with the applications and limitations of GC/MS, GC/PID, GC/FID, GC/ECD and GC/FPD. Tedlar bags, canisters, sorbent tubes and impingers were used during sampling, along with isokinetic tests methods for multiple metals and PAHs.

Air Toxics Testing of Glycol Reboiler Gas Processing Plant. Project manager for test program to determine emissions of BTXE from glycol reboiler vent at gas processing facility handling 12 MM/cfd of produced gas. Developed innovative test methods to accurately quantify BTXE emissions in reboiler vent gas.

Air Toxics Emissions Inventory Plan. Lead engineer for the development of generic air toxics emission estimating techniques (EETs) for oil and gas production equipment. This project was performed for the Western States Petroleum Association in response to the requirements of the California Air Toxics "Hot Spots" Act. EETs were developed for all point and fugitive oil and gas production sources of air toxics, and the specific air toxics associated with each source were identified. A pooled source emission test methodology was also developed to moderate the cost of source testing required by the Act.

Fugitive NMHC Emissions from TEOR Production Field. Project manager for the quantification of fugitive Nonmethane hydrocarbon (NMHC) emissions from a thermally enhanced oil recovery (TEOR) oil production field in Kern County, CA. This program included direct measurement of NMHC concentrations in storage tank vapor headspace and the modification of available NMHC emission factors for NMHC-emitting devices in TEOR produced gas service, such as wellheads, vapor trunklines, heat exchangers, and compressors. Modification of the existing NMHC emission factors was necessary due to the high concentration of CO_2 and water vapor in TEOR produced gases.

Fugitive Air Emissions Testing of Oil and Gas Production Fields. Project manager for test plan/test program to determine VOC and air toxics emissions from oil storage tanks, wastewater storage tanks and produced gas lines. Test results were utilized to develop comprehensive air toxics emissions inventories for oil and gas production companies participating in the test program.

Oil and Gas Production Field Air Emissions Inventory and Air Modeling. Project manager for oil and gas production field risk assessment. Project included review and revision of the existing air toxics emission inventory, air dispersion modeling, and calculation of the acute health risk, chronic non-carcinogenic risk and carcinogenic risk of facility operations. Results indicated that fugitive H_2S emissions from facility operations posed a potential health risk at the facility fenceline.

TITLE V PERMIT APPLICATION/MONITORING PLAN EXPERIENCE

Title V Permit Application San Diego County Industrial Facility. Project engineer tasked with preparing streamlined Title V operating permit for U.S. Navy facilities in San Diego. Principal emission units included chrome plating, lead furnaces, IC engines, solvent usage, aerospace coating and marine coating operations. For each device category in use at the facility, federal MACT requirements were integrated with District requirements in user friendly tables that summarized permit conditions and compliance status.

Title V Permit Application Device Templates - Oil and Gas Production Industry. Project manager and lead engineer to prepare Title V permit application "templates" for the Western States Petroleum Association (WSPA). The template approach was chosen by WSPA to minimize the administrative burden associated with listing permit conditions for a large number of similar devices located at the same oil and gas production facility. Templates are being developed for device types common to oil and gas production operations. Device types include: boilers, steam generators, process heaters, gas turbines, IC engines, fixed-roof storage tanks, fugitive components, flares, and cooling towers. These templates will serve as the core of Title V permit applications prepared for oil and gas production operations in California.

Title V Permit Application - Aluminum Rolling Mill. Project manager and lead engineer for Title V permit application prepared for largest aluminum rolling mill in the western U.S. Responsible for the overall direction of the permit application project, development of a monitoring plan for significant emission units, and development of a hazardous air pollutant (HAP) emissions inventory. The project involved extensive onsite data gathering, frequent interaction with the plant's technical and operating staff, and coordination with legal counsel and subcontractors. The permit application was completed on time and in budget.

Title V Model Permit - Oil and Gas Production Industry. Project manager and lead engineer for the comparative analysis of regional and federal requirements affecting oil and gas production industry sources located in the San Joaquin Valley. Sources included gas turbines, IC engines, steam generators, storage tanks, and process fugitives. From this analysis, a model applicable requirements table was developed for a sample device type (storage tanks) that covered the entire population of storage tanks operated by the industry. The U.S. EPA has tentatively approved this model permit approach, and work is ongoing to develop comprehensive applicable requirements tables for each major category of sources operated by the oil and gas industry in the San Joaquin Valley.

Title V Enhanced Monitoring Evaluation of Oil and Gas Production Sources. Lead engineer to identify differences in proposed EPA Title V enhanced monitoring protocols and the current monitoring requirements for oil and gas production sources in the San Joaquin Valley. The device types evaluated included: steam generators, stationary ICEs, gas turbines, fugitives, fixed roof storage tanks, and thermally enhanced oil recovery (TEOR) well vents. Principal areas of difference included: more stringent Title V O&M requirements for parameter monitors (such as temperature, fuel flow, and O_2), and more extensive Title V recordkeeping requirements.

RACT/BARCT/BACT EVALUATIONS

BACT Evaluation of Wool Fiberglass Insulation Production Line. Project manager and lead engineer for BACT evaluation of a wool fiberglass insulation production facility. The BACT evaluation was performed as a component of a PSD permit application. The BACT evaluation included a detailed analysis of the available control options for forming, curing and cooling sections of the production line. Binder formulations, wet electrostatic precipitators, wet scrubbers, and thermal oxidizers were evaluated as potential PM_{10} and VOC control options. Low NO_x burner options and combustion control modifications were examined as potential NO_x control techniques for the curing oven burners. Recommendations included use of a proprietary binder formulation to achieve PM_{10} and VOC BACT, and use of low-NO_x burners in the curing ovens to achieve NO_x BACT. The PSD application is currently undergoing review by EPA Region 9.

RACT/BARCT Reverse Jet Scrubber/Fiberbed Mist Eliminator Retrofit Evaluation. Project manager and lead engineer on project to address the inability of existing wet electrostatic precipitators (ESPs) and atomized mist scrubbers to adequately remove low concentration submicron particulate from high volume recovery boiler exhaust gas at the Alaska Pulp Corporation mill in Sitka, AK. The project involved thorough on-site inspections of existing control equipment, detailed review of maintenance and performance records, and a detailed evaluation of potential replacement technologies. These technologies included a wide variety of scrubbing technologies where manufacturers claimed high removal efficiencies on submicron particulate in high humidity exhaust gas. Packed tower scrubbers, venturi scrubbers, reverse jet scrubbers, fiberbed mist eliminators and wet ESPs were evaluated. Final recommendations included replacement of atomized mist scrubber with reverse jet scrubber and upgrading of the existing wet ESPs. The paper describing this project was published in the May 1992 TAPPI Journal.

Aluminum Smelter RACT Evaluation - Prebake. Project manager and technical lead for CO and PM_{10} RACT evaluation for prebake facility. Retrofit control options for CO emissions from the anode bake furnace, potline dry scrubbers and the potroom roof vents were evaluated. PM_{10} emissions from the coke kiln, potline dry scrubbers, potroom roof vents, and miscellaneous potroom fugitive sources were addressed. Four CO control technologies were identified as technologically feasible for potline CO emissions: potline current efficiency improvement through the addition of underhung busswork and automated puncher/feeders, catalytic incineration, recuperative incineration and regenerative incineration. Current efficiency improvement was identified as probable CO RACT if onsite test program demonstrated the effectiveness of this approach. Five PM_{10} control technologies were identified as technologically feasible: increased potline hooding efficiency through redesign of shields, the addition of a dense-phase conveying system, increased potline air evacuation rate, wet scrubbing of roof vent emissions, and fabric filter control of roof vent emissions. The cost of these potential PM_{10} RACT controls exceeded regulatory guidelines for cost effectiveness, though testing of modified shield configurations and dense-phase conveying is being conducted under a separate regulatory compliance order.

RACT/BACT Testing/Evaluation of PM_{10} Mist Eliminators on Five-Stand Cold Mill. Project manager and lead engineer for fiberbed mist eliminator and mesh pad mist eliminator comparative pilot test program on mixed phase aerosol (PM_{10})/gaseous hydrocarbon emissions from aluminum high speed cold rolling mill. Utilized modified EPA Method 5 sampling train with portion of sample gas diverted (after particulate filter) to Ratfisch 55 VOC analyzer. This was done to permit simultaneous quantification of aerosol and gaseous hydrocarbon emissions in the exhaust gas. The mesh pad mist eliminator demonstrated good control of PM_{10} emissions, though test results indicated that the majority of captured PM_{10} evaporated in the mesh pad and was emitted as VOC.

Aluminum Remelt Furnace/Rolling Mill RACT Evaluations. Lead engineer for comprehensive CO and PM_{10} RACT evaluation for the largest aluminum sheet and plate rolling mill in western U.S. Significant sources of CO emissions from the facility included the remelt furnaces and the coater line. The potential CO RACT options for the remelt furnaces included: enhanced maintenance practices, preheating combustion air, installation of fully automated combustion controls, and energy efficiency modifications. The coater line was equipped with an afterburner for VOC and CO destruction prior to the initiation of the RACT study. It was determined that the afterburner meets or exceeds RACT requirements for the coater line. Significant sources of PM_{10} emissions included the remelt furnaces and the 80-inch hot rolling mill. Chlorine fluxing in the melting and holding furnaces was identified as the principal source of PM_{10} emissions from the remelt furnaces. The facility is in the process of minimizing/eliminating fluxing in the melting furnaces, and exhaust gases generated in holding furnaces during fluxing will be ducted to a baghouse for PM_{10} control. These modifications are being performed under a separate compliance order, and were determined to exceed RACT requirements. A water-based emulsion coolant and inertial separators are currently in use on the 80-inch hot mill for PM_{10} control. Current practices were determined to meet/exceed PM_{10} RACT for the hot mill. Tray tower absorption/recovery systems were also evaluated to control PM_{10} emissions from the hot mill, though it was determined that the technical/cost feasibility of using this approach on an emulsion-based coolant had not yet been adequately demonstrated.

BARCT Low NO_x Burner Conversion – Industrial Boilers. Lead engineer for evaluation of low NO_x burner options for natural gas-fired industrial boilers. Also evaluated methanol and propane as stand-by fuels to replace existing diesel stand-by fuel system. Evaluated replacement of steam boilers with gas turbine co-generation system.

BACT Packed Tower Scrubber/Mist Eliminator Performance Evaluations. Project manager and lead engineer for Navy-wide plating shop air pollution control technology evaluation and emissions testing program. Mist eliminators and packed tower scrubbers controlling metal plating processes, which included hard chrome, nickel, copper, cadmium and precious metals plating, were extensively tested at three Navy plating shops. Chemical cleaning and stripping tanks, including hydrochloric acid, sulfuric acid, chromic acid and caustic, were also tested. The final product of this program was a military design specification for plating and chemical cleaning shop air pollution control systems. The hydrochloric acid mist sampling procedure developed during this program received a protected patent.

BACT Packed Tower Scrubber/UV Oxidation System Pilot Test Program. Technical advisor for pilot test program of packed tower scrubber/ultraviolet (UV) light VOC oxidation system controlling VOC emissions from microchip manufacturing facility in Los Angeles. The testing was sponsored in part by the SCAQMD's Innovative Technology Demonstration Program, to demonstrate this innovative control technology as BACT for microchip manufacturing operations. The target compounds were acetone, methylethylketone (MEK) and 1,1,1-trichloroethane, and compound concentrations ranged from 10-100 ppmv. The single stage packed tower scrubber consistently achieved greater than 90% removal efficiency on the target compounds. The residence time required in the UV oxidation system for effective oxidation of the target compounds proved significantly longer than the residence time predicted by the manufacturer.

BACT Pilot Testing of Venturi Scrubber on Gas/Aerosol VOC Emission Source. Technical advisor for project to evaluate venturi scrubber as BACT for mixed phase aerosol/gaseous hydrocarbon emissions from deep fat fryer. Venturi scrubber demonstrated high removal efficiency on aerosol, low efficiency on VOC emissions. A number of VOC tests indicated negative removal efficiency. This anomaly was traced to a high hydrocarbon concentration in the scrubber water. The pilot unit had been shipped directly to the jobsite from another test location by the manufacturer without any cleaning or inspection of the pilot unit.

Pulp Mill Recovery Boiler BACT Evaluation. Lead engineer for BACT analysis for control of SO_2, NO_x, CO, TNMHC, TRS and particulate emissions from the proposed addition of a new recovery furnace at a kraft pulp mill in Washington. A "top down" approach was used to evaluate potential control technologies for each of the pollutants considered in the evaluation.

Air Pollution Control Equipment Design Specification Development. Lead engineer for the development of detailed Navy design specifications for wet scrubbers and mist eliminators. Design specifications were based on field performance evaluations conducted at the Long Beach Naval Shipyard, Norfolk Naval Shipyard, and Jacksonville Naval Air Station. This work was performed for the U.S. Navy to provide generic design specifications to assist naval facility engineering divisions with air pollution control equipment selection. Also served as project engineer for the development of Navy design specifications for ESPs and fabric filters.

CONTINUOUS EMISSION MONITOR (CEM) PROJECT EXPERIENCE

Process Heater CO and NO_x CEM Relative Accuracy Testing. Project manager and lead engineer for process heater CO and NO_x analyzer relative accuracy test program at petrochemical manufacturing facility. Objective of test program was to demonstrate that performance of onsite CO and NO_x CEMs was in compliance with U.S. EPA "Boiler and Industrial Furnace" hazardous waste co-firing regulations. A TECO Model 48 CO analyzer and a TECO Model 10 NO_x analyzer were utilized during the test program to provide $\pm$1 ppm measurement accuracy, and all test data was recorded by an automated data acquisition system. One of the two process heater CEM systems tested failed the initial test due to leaks in the gas conditioning system. Troubleshooting was performed using O_2 analyzers, and the leaking component was identified and replaced. This CEM system met all CEM relative accuracy requirements during the subsequent retest.

Performance Audit of NO_x and SO_2 CEMs at Coal-Fired Power Plant. Lead engineer on system audit and challenge gas performance audit of NO_x and SO_2 CEMs at a coal-fired power plant in southern Nevada. Dynamic and instrument calibration checks were performed on the CEMs. A detailed visual inspection of the CEM system, from the gas sampling probes at the stack to the CEM sample gas outlet tubing in the CEM trailer, was also conducted. The CEMs passed the dynamic and instrument calibration requirements specified in EPA's Performance Specification Test - 2 (NO_x and SO_2) alternative relative accuracy requirements.

LATIN AMERICA ENVIRONMENTAL PROJECT EXPERIENCE

Preliminary Design of Ambient Air Quality Monitoring Network Lima, Peru. Project leader for project to prepare specifications for a fourteen station ambient air quality monitoring network for the municipality of Lima, Peru. Network includes four complete gaseous pollutant, particulate, and meteorological parameter monitoring stations, as well as eight PM_{10} and TSP monitoring stations.

Evaluation of Proposed Ambient Air Quality Network Modernization Project Venezuela. Analyzed a plan to modernize and expand the ambient air monitoring network in Venezuela. Project was performed for the U.S. Trade and Development Agency. Direct interaction with policy makers at the Ministerio del Ambiente y de los Recursos Naturales Renovables (MARNR) in Caracas was a major component of this project.

Evaluation of U.S.-Mexico Border Region Copper Smelter Compliance with Treaty Obligations Mexico. Project manager and lead engineer to evaluate compliance of U.S. and Mexican border region copper smelters with the SO_2 monitoring, recordkeeping and reporting requirements in Annex IV [Copper Smelters] of the La Paz Environmental Treaty. Identified potential problems with current ambient and stack monitoring practices that could result in underestimating the impact of SO_2 emissions from some of these copper smelters.

Identified additional source types, including hazardous waste incinerators and power plants, that should be considered for inclusion in the La Paz Treaty process.

Development of Air Emission Limits for ICE Cogeneration Plant - Panamá. Lead engineer assisting U.S. cogeneration plant developer to permit an ICE cogeneration plant at a hotel/casino complex in Panama. Recommended the use of modified draft World Bank NO_x and PM limits for ICE power plants. The modification consisted of adding a thermal efficiency factor adjustment to the draft World Bank NO_x and PM limits. These proposed ICE emission limits are currently being reviewed by Panamanian environmental authorities.

Mercury Emissions Inventory for Stationary Sources in Northern Mexico. Project manager and lead engineer to estimate mercury emissions from stationary sources in Northern Mexico. Major potential sources of mercury emissions include solid- and liquid-fueled power plants, cement kilns co-firing hazardous waste, and non-ferrous metal smelters. Emission estimates were provided for approximately eighty of these sources located in Northern Mexico. Coordinated efforts of two Mexican subcontractors, located in Mexico City and Hermosillo, to obtain process throughput data for each source included in the inventory.

Translation of U.S. EPA Scrap Tire Combustion Emissions Estimation Document Mexico. Evaluated the Translated a U.S. EPA scrap tire combustion emissions estimation document from English to Spanish for use by Latin American environmental professionals.

Environmental Audit of Aluminum Production Facilities Venezuela. Evaluated the capabilities of existing air, wastewater and solid/hazardous waste control systems used by the aluminum industry in eastern Venezuela. This industry will be privatized in the near future. Estimated the cost to bring these control systems into compliance with air, wastewater and solid/hazardous waste standards recently promulgated in Venezuela. Also served as technical translator for team of U.S. environmental engineers involved in the due diligence assessment.

Assessment of Environmental Improvement Projects Chile and Peru. Evaluated potential air, water, soil remediation and waste recycling projects in Lima, Peru and Santiago, Chile for feasibility study funding by the U.S. Trade and Development Agency. Project required onsite interaction with in-country decisionmakers (in Spanish). Projects recommended for feasibility study funding included: 1) an air quality technical support project for the Santiago, Chile region, and 2) soil remediation/metals recovery projects at two copper mine/smelter sites in Peru.

Air Pollution Control Training Course Mexico. Conducted two-day Spanish language air quality training course for environmental managers of assembly plants in Mexicali, Mexico. Spanish-language course manual prepared by Powers Engineering. Practical laboratory included training in use of combustion gas analyzer, flame ionization detector (FID), photoionization detector (PID), and occupational sampling.

Stationary Source Emissions Inventory Mexico. Developed a comprehensive air emissions inventory for stationary sources in Nogales, Sonora. This project requires frequent interaction with Mexican state and federal environmental authorities. The principal Powers Engineering subcontractor on this project is a Mexican firm located in Hermosillo, Sonora.

VOC Measurement Program Mexico. Performed a comprehensive volatile organic compound (VOC) measurements program at a health products fabrication plant in Mexicali, Mexico. An FID and PID were used to quantify VOCs from five processes at the facility. Occupational exposures were also measured. Worker exposure levels were above allowable levels at several points in the main assembly area.

Renewable Energy Resource Assessment Proposal Panama. Translated and managed winning bid to evaluate wind energy potential in Panama. Direct interaction with the director of development at the national utility monopoly (IRHE) was a key component of this project.

Comprehensive Air Emissions Testing at Assembly Plant Mexico. Project manager and field supervisor of emissions testing for particulates, NO_x, SO_2 and CO at turbocharger/air cooler assembly plant in Mexicali, Mexico. Source specific emission rates were developed for each point source at the facility during the test program. Translated test report into Spanish for review by the Mexican federal environmental agency (SEMARNAP).

Air Pollution Control Equipment Retrofit Evaluation Mexico. Project manager and lead engineer for comprehensive evaluation of air pollution control equipment and industrial ventilation systems in use at assembly plant consisting of four major facilities. Equipment evaluated included fabric filters controlling blast booth emissions, electrostatic precipitator controlling welding fumes, and industrial ventilation systems controlling welding fumes, chemical cleaning tank emissions, and hot combustion gas emissions. Recommendations included modifications to fabric filter cleaning cycle, preventative maintenance program for the electrostatic precipitator, and redesign of the industrial ventilation system exhaust hoods to improve capture efficiency.

Comprehensive Air Emissions Testing at Assembly Plant Mexico. Project manager and field supervisor of emissions testing for particulates, NO_x, SO_2 and CO at automotive components assembly plant in Acuña, Mexico. Source-specific emission rates were developed for each point source at the facility during the test program. Translated test report into Spanish.

Fluent in Spanish. Studied at the Universidad de Michoacán in Morelia, Mexico, 1993, and at the Colegio de España in Salamanca, Spain, 1987-88. Have lectured (in Spanish) on air monitoring and control equipment at the Instituto Tecnológico de Tijuana. Maintain contact with Comisión Federal de Electricidad engineers responsible for operation of wind and geothermal power plants in Mexico, and am comfortable operating in the Mexican business environment.

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AWARDS

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Engineer of the Year, 1986 – Naval Energy and Environmental Support Activity, Port Hueneme
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PATENTS

Sedimentation Chamber for Sizing Acid Mist, Navy Case Number 70094