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Exhibit No.:	
Witness:	Dr. Udi Helman
Commissioner:	Michael R. Peevey
ALJ:	Peter V. Allen

PREPARED DIRECT TESTIMONY OF DR. UDI HELMAN

ON BEHALF OF THE LARGE-SCALE SOLAR ASSOCIATION

August 4, 2011

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Prepared Direct Testimony of Dr. Udi Helman

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ON BEHALF OF THE LAR GE-SCALE SOLAR ASSOCIATION

1. Introduction

Q. What is your name and by whom are you employed?

A. My name is Udi Helman and I am employed by BrightSource Energy as Director, Economic and Pricing Analysis. I have held this position since January 2011.

Q. Please describe your educational and professional background.

A. Prior to working at BrightSource Energy, I worked as Principal Economist at the California Independent System Operator Corporation (CAISO), where among other things, I worked on developing the methodologies for the CAISO's studies of renewable integration and am a co-author of the CAISO's study of integration at 20% RPS. Prior to joining the CAISO in 2007, I worked for 10 years as an economist at the Federal Energy Regulatory Commission (FERC) in Washington D.C. In that capacity, I worked on electricity market design issues, including wholesale energy, ancillary service and installed capacity markets, transmission usage pricing and transmission property rights. I have a PhD in energy economics from The Johns Hopkins University, Baltimore, MD, and a BA and MA from University of Toronto, Canada.

Q. What is the purpose of your testimony?

A. The purpose of my testimony is to present and support the Large-scale Solar Association (LSA)'s position regarding integration analysis and modeling results conducted in Track I of this Long Term Procurement Plan proceeding (LTPP). I focus on the advantages and limitations of the modeling framework and the assumptions used for the analysis and make recommendations for continued work to refine the analysis.

2. Discussion of Track I Integration Analysis and Modeling Results

Q. Do you agree with the recommendation in the Joint Investor-Owned Utility (IOU) Testimony[1] that "the Commission should not make a definitive finding in this proceeding either of resource need, or of the lack of resource need, associated with the integration of intermittent renewable resource power into the CAISO grid"?

A. Yes. Based on the assumptions, scenarios, and modeling used to perform the analysis conducted as part of Track I of this proceeding, no definitive finding could be reached that new generic resources are needed to meet system operational requirements in 2020. This conclusion was reached after several months of model refinement and evaluation. However, LSA believes that this analysis should be continued using refined assumptions and improved modeling techniques, as described in more detail below. In particular, LSA is interested in evaluation of renewable technology options to facilitate integration. Clarifying the technology options in timely fashion is necessary as this modeling analysis will likely be conducted again in future LTPP proceedings.

Q. What are the key lessons that should be drawn from the renewables integration analysis presented in this LTPP?

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[1] Southern California Edison Company, Pacific Gas and Electric Company, San Diego Gas & Electric Company, System Resource Plan, Joint Investor-Owned Utilities Supporting Testimony (Joint IOU Testimony), dated July 1, 2011, at p. 1-3, lines 4-7.

A. The LTPP Track I analysis offers a number of key lessons. I offer some general observations about the modeling methods, the timing of the results, and the need to continue the analysis with stakeholder participation. Further details follow in the responses to subsequent questions on particular items.

With respect to analysis, I believe that a key lesson that can be drawn from this analysis, as well as many others that have been conducted in California[2] and other parts of the country[3], is that despite the uncertainties in the assumptions and difficulty of the analysis, it is critical to continue the development of an increasingly sophisticated analytical basis to support cost-effective investments that meet environmental policy goals while preserving power system reliability. As a result of the integration analysis presented in Track I, and the ongoing integration studies at the CAISO[4] and other agencies, there is now a foundation of replicable simulation models that can be refined over time as well as augmented by other types of models

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[2] See, e.g., California Energy Commission (2007), "Intermittency Analysis Project", CEC -500-2007-081 at http://www.energy.ca.gov/2007publications/CEC-500-2007-081/CEC-500-2007-081.PDF; CAISO (2007), Integration of Renewable Resources – Transmission and Operating Issues and Recommendations for Integrating Renewable Resources on the ISO-Controlled Grid; KEMA (2010), Research Evaluation of Wind Generation, Solar Generation, and Storage Impact on the California Grid; California Independent System Operator Corp. (CAISO) (2010) Integration of Renewable Resources: Operational Requirements and Generation Fleet Capability at 20% RPS, August 31, 2010, available at http://www.caiso.com/Documents/Integration-RenewableResources-OperationalRequirementsandGenerationFleetCapabilityAt20PercRPS.pdf (CAISO 20% study)

[3] M. Milligan, et.al. National Renewable Energy Laboratory (NREL), C. Clark, et.al. U.S. Department of Energy (DOE), (2011) Cost-Causation and Integration Cost Analysis for Variable Generation, available at: http://www.nrel.gov/docs/fy11osti/51860.p df; M. Milligan, et al. (2011 Milligan Paper), Large-Scale Wind Integration Studies in the United States: Preliminary Results, Conference Paper, NREL/CP-550-46527, September 2009; Ontario Power Authority, Independent Electricity System Operator, Canadian Wind Energy Association, "Ontario Wind Integration Study," available at http://www.uwig.org/OPA -Report-200610-1.pdf; Electrical Reliability Council of Texas, "Analysis of Wind Gene ration Impact on ERCOT Ancillary Services Requirements," available at http://www.ercot.com/news/presentations/2008/Wind_Generation_Impact_on_Ancillary_Services_-_GE_Study.zip.; GE Energy/ NREL, May 2010, Western Wind and Solar Study, NREL, Golden, Colorado .

[4] See CAISO 20% study, note 2 infra; CAISO, Supplement to August 2010 Report on the Integration of Renewable Resources Operational Requirements and Generation Fleet Capability at 20% RPS (May 31, 2011), available at http://www.caiso.com/Documents/Supplement_August2010Report_Integration_RenewableResourcesOperationalRequirements_GenerationFleetCapability_20RPS.pdf (CAISO 20% supplemental analysis).

and analytical tools. In addition, the CAISO has made efforts to validate some aspects of the modeling against actual system operations, a process which should continue.[5]

Notably, at this time, and given the present state of knowledge, the LTPP simulations did not demonstrate the need for additional resources to support integration of the level of renewable generation resources required under the 33% Renewable Portfolio Standard (RPS), but have raised a large number of questions for further examination. This finding is reasonable both on the basis of the modeling results to date and because there is further time available for further refinement. The CAISO's 20% RPS study and its associated supplemental analysis[6] – both of which evaluate less dramatic changes on the power system over a 1-3 year look-ahead – have suggested that California's existing generator fleet has sufficient residual capability to integrate the renewable generation expected on-line in that period and perhaps accommodate additional renewable generation beyond what is expected over the next 1-3 years. Arguably, then, the LTPP and related proceedings have at least one more year to continue to evaluate the operational needs and technology options associated with renewable integration over longer time horizons before commitments must be made to procure new resources specifically to address renewable integration requirements. But that breathing room needs to be used efficiently to ensure that the integration analysis started in this proceeding continues on an uninterrupted basis even after this proceeding ends.

A second lesson is the value of coordination and communication among the state energy agencies and stakeholders. The LTPP and CAISO process for modeling 33% RPS was more

[5] Id.
[6] Id.

inclusive and transparent than most such efforts. As a result, participant understanding of integration issues and power system challenges has grown considerably over the past 18 months of integration studies. Also, market participants, such as renewable developers and natural gas plant owners, most of whom could not in themselves support large-scale systems modeling at this level of detail have had the benefit of gaining additional insight into the operational capabilities of the power system and can now leverage some of the results in advancing technology options to address projected integration needs. This is a major improvement over the situation just 12 months ago. Hence, irrespective of the outcome of this proceeding, the market can begin to respond to the analysis by modifying the design of next generation renewable technologies and pursuing storage and other technology options. The dialogue and momentum created in this proceeding should be sustained on a coordinated basis.

A third lesson from this proceeding is that we should promptly complete the critical tasks left unfinished in the current analysis in order to have a solid foundation for the development of appropriate market-based mechanisms to respond to integration needs efficiently and cost-effectively. One important task that was not completed in the analysis presented in Track I is consideration of a range of potential solutions to integration requirements, including those that can be provided by demand response, storage and renewable technologies. The renewable technology market has begun to achieve higher levels of maturity, and can respond to higher quality information about potential system integration requirements and costs. More explicit valuation of market, operational and reliability attributes provides renewable energy companies with the information needed to invest in improving renewable energy technology in ways that reduce integration costs to the power system and hence to wholesale buyers and ratepayers. The information will enable greater technology innovation and lead to products and projects that better match power system needs.

Q. What are the primary strengths and weaknesses of the analysis?

A. The primary strength of the study is the use of a detailed statistical model of future operational requirements ("Step 1") coupled with a detailed production simulation model of the California and western power system ("Step 2"). This basic modeling framework, variants of which have been used in many prior and ongoing integration studies,[7] allows for consideration both of intra-hourly variability and forecast error while optimizing commitment and dispatch of integration resources over an entire year. By incorporating the need to turn on additional generation to provide intra-hourly "net" load-following reserves, as well as any additional regulation, the production simulation model incorporates important operational and market constraints that will occur at 33% RPS. Further refinement of the modeling representation of some of these requirements, such as load-following capacity requirements, should be evaluated in subsequent phases. Moreover, the modeling framework has capabilities for integration analysis that have not yet been fully exploited, as discussed below.

One weakness that has become readily apparent is the long lead-time in developing large-scale systems models to support analysis of renewable integration, as well as long solution times that can limit the examination of sensitivities within the time-lines of the proceeding. However, in this case, I believe that the models used here should continue to be used as a component of

[7] See, e.g., studies and analysis referenced2011 Milligan Paper, note 2 infra.

integration analysis, as well as possibly complemented by other modeling methods. This proceeding should thus make a finding and adopt recommendations about the need for analytical continuity and refinement, as well as establish an on-going process to carry out those recommendations, as I propose below. The CAISO has efforts underway to establish its shorter-term analysis of integration requirements and capabilities as a complement to the ongoing annual local capacity requirement (LCR) analysis. [8] Ultimately, a suite of standardized and validated shorter-term (1-3 years) and longer-term (5-10 years) models should be created. This suite of models could then be used, with appropriate modifications over time to fit changing technology and grid conditions, to inform both CAISO and Commission proceedings addressing renewable integration and procurement issues.

Another weakness is that the analysis did not include some types of modeling that could have provided additional useful data on operational requirements and performance. The statistical model used in Step 1 itself is a flexible model that was used in the CAISO's earlier 20% RPS study to explore many details about the relationship of forecast error and variability, and the differential effect of different technologies; however, there was not sufficient time to explore similar qualities in the 33% RPS analysis performed for Track I. For example, the Step 1 statistical model can track the duration an inferred ramp rate for intra-hourly timeframes (e.g., 1-minute, 5-minute intervals) through a specialized algorithm which merits further exploration. The statistical model can also be easily modified to examine the effect of adding capability for renewable technologies to smooth or adjust their production levels through, for example, the addition of storage or supplemental gas firing (for solar thermal plants) or even through

[8] See, e.g., studies and analysis referenced in note 4, infra.

selective curtailment of wind and solar ramps. Under certain times and conditions, it will likely be more cost-effective to pay for curtailment rather than to build new assets for integration, and the analysis should evaluate whether and under what conditions this hypothesis is correct.

Q. Are there key assumptions driving the integration study outcome which require further analysis and review?

A. Clearly, there are a number of assumptions that could affect the results in a large-scale model of the Western Electricity Coordinating Council (WECC) power system. These include notably the assumptions about load levels in the years modeled, the mix and location of renewable resources, the transmission network, the estimated operational requirements for renewable integration as a function of forecast error and variability, the operational parameters modeled for the generation fleet, the characteristics of that fleet over time, and how the rest of the WECC (outside California) is modeled. Many of these assumptions have been examined and reviewed with stakeholders over the course of the proceeding, and can appropriately be used as the basis for further progress if our recommendations to continue integration analysis are followed. However, some of the inputs should be revised as part of any continued integration analysis.

From the perspective of LSA, one factor that remains of particular concern is the modeling of solar forecasting and its effect on plant operations. For at least some of the large-scale solar plants being modeled, the assumptions of the model about plant operations require further analysis, as the CAISO acknowledged in its testimony.[9] In the analysis of solar variability and

[9] See Testimony of Mark Rothleder, p. 32, line 27 – p. 33, line 2.

forecast errors conducted so far, further research is needed to refine modeling of plant-scale effects, operational properties and performance capabilities of different solar technologies, particularly for utility-scale projects. Several of these considerations are apparent in the methodologies used to describe, and data presented, on solar thermal plants. First, given the lack of operating experience with utility-scale solar thermal plants, the analysis was based on scaling up 1 MW plant sizes from the National Renewable Energy Laboratory (NREL) System Advisor Model (SAM).[10] Using this approach may not accurately reflect the start-up characteristics of large-scale plants; e.g., whereas the model suggested a rapid ramp up at the morning start, the actual start-up and ramp-up time could be slower, depending on the technology, or modulated by operational capabilities such as thermal storage. Second, while the modeling did attempt to capture some degree of inertial delay for solar thermal plants using an algorithm, the results may not appropriately reflect how in operational practice, a solar thermal plant's output is moderated by the thermal mass of the system (e.g., the solar receiver and the working fluid) and other factors. For example, given the size of the solar field and the thermal inertia, typical cloud transients in solar field can take up to 30 minutes to be realized at the steam turbine, greatly reducing weather-related volatility. Moreover, depending on the plant design, operators will have more operating parameters to address how the plant's inertia is adjusted and combined with other plant characteristics, such as supplemental gas augmentation and storage, to manage deviations from schedules. Specifically, for solar thermal plants with supplemental gas, intermittency can be regulated through the careful use of de minimis natural gas backup to prevent turbine trips during periods of transient

[10] Available at https://www.nrel.gov/analysis/sam/.

clouds. For solar thermal plants in general, there is the inherent capability to implement or expand thermal storage, and several projects with storage have been advanced for operation by 2020. However, the LTPP Track I analysis did not consider these operational capabilities or technology options. In combination, these capabilities could substantially reduce or even eliminate the integration requirements associated with solar thermal plants by 2020. Hence more sophisticated modeling techniques need to be developed for future analysis purposes to better capture the system integration requirements of alternative configurations of solar thermal plants.

Another related area of concern is the postponement of Phase 2 of the CAISO's integration modeling, which will consider a range of integration resources other than gas-fired generation. We understand the reasons for this delay, but believe that it is necessary to complete that modeling prior to approving procurement of any new resources to meet flexibility requirements associated with renewable generation. I discuss that further below.

Q. Do you recommend changes in the sensitivity cases being examined in the integration analysis?

A. In general, any large-scale modeling effort has to limit the number of sensitivity cases. However, the integration analysis presented in this LTPP could examine some sensitivity cases that could provide important information both for the California renewables market and for system resource planning. In addition to the further analysis identified in testimony by the CAISO and the IOUs jointly, these could include hydro sensitivity cases.

Annual variations in hydro-electric generation may have increasing potential to impact renewable production as the level of renewable resources grows. In low hydro years, the possibility of overgeneration in the CAISO-controlled system is lower than that experienced during an average hydro year, while in high hydro years, instances of overgeneration could be more frequent (depending on many factors, such as the ability to reduce imports or increase exports).[11] Given the 20-year or longer term of most renewable power purchase agreements, it is important to develop a better understanding of the expected frequency of overgeneration and potential curtailment under varying hydro conditions.

Of the existing scenarios, LSA believes that only the Day-Ahead Forecast Error scenario described in the Joint IOU Supporting Testimony raises fundamental methodological questions about the modeling that need to be examined further. It currently provides limited insights because it rests on assumptions about market structure that may not be valid when 33% RPS is achieved. While it is true that the CAISO has a day-ahead market that includes procurement of 100% of ancillary services, which includes regulation and possibly a future load-following reserve, there are many reasons why that structure may need to be modified when renewable generation reaches the level required under 33% RPS. For example, both the FERC Notice of Inquiry on Variable Energy Resources[12] and some of the CAISO's own scoping papers for market design changes to support renewable integration[13], contain discussion of changes to market

[11] See, e.g., the findings in the CAISO 20% study, note 2 infra.
[12] 130 FERC ¶ 61,053, (Docket No. RM10-11-000) Integration of Variable Energy Resources (Issued January 21, 2010).
[13] See, e.g., CAISO, Discussion & Scoping Paper on Renewable Integration Phase 2, Renewable Integration: Market and Product Review Phase 2 (April 5, 2010), available at http://www.caiso.com/Documents/Renewable%20integration%20market%20and%20product%20review%20phas

design. These could include moving the CAISO day-ahead market closer in time to real-time operations; procuring less than 100% of ancillary services needed for integration day-ahead, and then perhaps utilizing the CAISO residual unit commitment and the real-time market to procure additional reserves for integration; and changing the time-lines in the "day-of market" to further facilitate scheduling of wind and solar. In short, the Day-Ahead Forecast Error case is likely to be inconsistent with changes to future market design that mitigate integration costs and so needs further refinement.

Q. Is it appropriate to consider only gas-fired generation in meeting integration needs? What other resources should be considered and why?

A. No. It is clearly not appropriate to consider only gas-fired generation to meet integration needs, particularly given California's commitment to environmental policy goals that extend to 2020 and beyond. The existing gas-fired generation fleet is a vital asset for both integration and reliability services in the CAISO and WECC markets. Since gas-fired generation is expected to be the low-cost provider of integration services over the next few years, consideration of a gas-only integration benchmark was appropriate for the analysis.

However, any new investments in infrastructure should also consider future needs under California's commitment to an increasingly restrictive carbon emissions future. The Track I analysis did include 4,817 MW of incremental demand response for peak reduction purposes and did conduct a case with a third pump operating at Helms. However, the evaluation of alternatives to gas-fired generation for meeting flexibility needs must be substantially

e%202%20-%20papers%20and%20proposals/DiscussionandScopingPaper-RenewableIntegrationMarketandProductReviewPhase2.pdf.

expanded, for at least two reasons. First, future integration requirements will require demand response to operate not just for peak load reductions, but also possibly to address renewable ramps, particularly in the late morning and early evening. Second, other types of storage in addition to pumped hydro storage may become cost-effective in the 2020 time horizon, and certainly beyond.

In fact, the CAISO has recognized the need for a next phase of integration analysis that considered alternative integration resources (sometimes referred to as "Phase 2"). LSA believes that this phase of the analysis should begin in timely fashion in the fall of 2011 and be coordinated with any other integration research efforts that are underway.

3. Summary of LSA's recommendations regarding completion of renewable integration analysis.

Q. Please summarize LSA's recommendations regarding completion of renewable integration analysis.

A. LSA recommends that the integration analysis continue in the remainder of 2011 and through 2012 as required for completion of the work outlined below. We recommend the continuation of a smaller technical working group on integration modeling organized by the CAISO with limited participation (to allow for reasonably efficient meetings) that includes 1-2 representatives of each technology sector and of the consumer and environmental organizations that have been active participants in this proceeding, the IOUs and POUs, and the other state energy agencies. The working group would focus on improved modeling, not policy. This group would be further tasked with incorporating data from related studies into the integration modeling framework, such as the study of system inertia under 33% RPS that the CAISO will complete in late 2011. The group can also help with further review of the technical literature on integration analysis.

At the same time, the Commission should continue to conduct periodic meetings/workshops with LTPP technical and non-technical stakeholders who elect to continue involvement and provide greater transparency. The CAISO would prepare periodic reports with status and recommendations for analysis. At the start of the next LTPP, the CAISO should provide a work plan and propose a schedule to complete the analysis, including providing opportunity for stakeholder comments, to serve as the basis for a scoping memo.

In terms of substance, LSA emphasizes the need for a more detailed examination of intra-hourly flexibility requirements, including the effects on integration requirements of forecast error, and operational attributes of different renewable technologies, including large-scale solar PV and solar thermal technologies (with and without storage). We also strongly support completion of the Phase 2 analysis to evaluate alternative integration solutions. For purposes of clarifying curtailment risk associated with overgeneration conditions, we would suggest more sensitivities of different hydro years. We also recommend further evaluation of changes to imports and exports to California with consideration of the impact of planned transmission infrastructure improvements.

Q. **Does this conclude your testimony?**

A. Yes, it does.

STATEMENT OF QUALIFICATIONS OF DR. UDI HELMAN

Q Please state your name and business address.

A My name is Udi Helman and my business address is 1999 Harrison Street, Suite 2150, Oakland, CA 94612.

Q Who is your present employer and what is your position?

A I am employed by BrightSource Energy as Director, Economic and Pricing Analysis.

Q Please summarize your professional background.

A Prior to my employment with BrightSource, I worked as Principal Economist with the California Independent System Operator Corporation (CAISO). In that position I focused on market design and policy analysis in the Market & Infrastructure Development Division of the CAISO. I worked on renewable integration, including determining operational requirements and cost impacts, and scenario methodologies and policy issues associated with transmission planning to interconnect renewables on a large scale and long-term procurement planning. I worked extensively on the CAISO's recent study of operational requirements under a 20% RPS. Prior to joining CAISO in August 2007, I worked at the Federal Energy Regulatory Commission (FERC) in Washington, D.C. In that capacity, I worked extensively on electricity market design issues, including wholesale energy, ancillary service and installed capacity markets, transmission usage pricing and transmission property rights. Upon joining FERC in 1998, I worked initially on the Northeastern ISO markets, notably the start-up of the ISO-New England market and its subsequent re-design in 2003. I also worked on the Standard Market Design

(SMD) initiative in 2002 and subsequently on the start-up and development of the Midwest ISO markets (2003-05). Before leaving FERC, I was lead for the Long-Term Transmission Rights team. I have presented on market design and market modeling at, among other venues, conferences and workshops organized by the Department of Energy (DOE), Energy Modeling Forum (EMF), NARUC, IEEE, and INFORMS as well as before audiences at California ISO, California Public Utilities Commission (CPUC), FERC, EIA, EPRI, NSF, EUCI, and elsewhere.

My recent papers, most jointly authored, include "Integration of Wind and Solar Energy in the California Power System: Results from Simulations of a 20% Renewable Portfolio Standard," paper presented at the UCEI POWER conference, Berkeley, CA, March 2011; "RTOs, Regional Electricity Markets, and Climate Policy," in F.P. Sioshansi, ed., *Generating Electricity in a Carbon-Constrained World*, Elsevier, 2010; "Large-Scale Market Power Modeling: Analysis of the U.S. Eastern Interconnection and Regulatory Applications" *IEEE Transactions on Power Systems* (2010); "The Design of US Wholesale Energy and Ancillary Service Auction Markets: Theory and Practice," in F. P. Sioshansi, ed. *Competitive Electricity Markets: Design, Implementation, Performance*, Elsevier (2008); "Independent System Operators in the USA: History, Lessons Learned, and Prospects," in F.P. Sioshansi, W. Pfaffenberger, eds. *Electricity Market Reform: An International Perspective*, Elsevier (2006); "Market power monitoring and mitigation in the US wholesale power markets" *Energy* (2006); "Dispatchable Transmission in RTO Markets," *IEEE Transactions on Power Systems* (February 2005); and "A Primer on Complementarity-Based Equilibrium Modeling for Electric Power Markets," in D.W. Bunn, ed., *Modeling Prices in Competitive Electricity Markets* (Wiley, 2004) . Other technical and policy papers have appeared in *IEEE Transactions on Power Systems*, *The Journal of NeuroComputing* and *The Washington Quarterly*.

Q. Please describe your educational background.

A. I have a BA (1987) and MA (1990) degrees from the University of Toronto and a PhD (2003) from The Johns Hopkins University in applied economics and systems analysis.

Q. Have you previously testified at a hearing before the California Public Utilities Commission?

A. No. However, while at CAISO, I was a presenter at several Commission workshops.

Q. What is the purpose of your testimony?

A. The purpose of my testimony is to sponsor the Prepared Direct Testimony Of Dr. Udi Helman On Behalf Of The Large-scale Solar Association in Track I (System Plan) of R.10-05-006 (Long Term Procurement Plan (LTPP)).

Q. Does this conclude your statement of qualifications?

A. Yes, it does.