

RENEWABLE RESOURCE INTEGRATION PROJECT – SCOPING STUDY OF STRATEGIC TRANSMISSION OPERATIONS, AND RELIABILITY ISSUES

Prepared For:
California Energy Commission
Public Interest Energy Research Program

Prepared By:
Consortium for Electric Reliability Technology
Solutions/Electric Power Group



Arnold Schwarzenegger
Governor

PIER FINAL PROJECT REPORT

December 2008
CEC-500-2008-081

Prepared By:

Electric Power Group
Vikram Budhraja, John Ballance, Jim Dyer, Fred Mobasher
Pasadena, California 91101

Joseph Eto
Lawrence Berkeley National Laboratory
Berkeley, California 94720

Commission Contract No. 500-02-004
Commission Work Authorization No. MRA-047

Prepared For:

Public Interest Energy Research (PIER)
California Energy Commission

Clare Laufenberg Gallardo
Contract Manager

Ken Koyama
Office Manager
Energy Generation Research Office

Martha Krebs, Ph.D.
PIER Director

Thom Kelly, Ph.D.
Deputy Director
ENERGY RESEARCH & DEVELOPMENT DIVISION

Melissa Jones
Executive Director



DISCLAIMER

This report was prepared as the result of work sponsored by the California Energy Commission. It does not necessarily represent the views of the Energy Commission, its employees or the State of California. The Energy Commission, the State of California, its employees, contractors and subcontractors make no warrant, express or implied, and assume no legal liability for the information in this report; nor does any party represent that the uses of this information will not infringe upon privately owned rights. This report has not been approved or disapproved by the California Energy Commission nor has the California Energy Commission passed upon the accuracy or adequacy of the information in this report.

Acknowledgements

The research team wishes to thank Don Kondoleon, project manager, for his guidance, support, and encouragement throughout the project.

Preface

The California Energy Commission's Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

Renewable Resource Integration Project—Scoping Study of Strategic Transmission, Operations, and Reliability Issues is the final report for the PIER project (contract number 500-02-004, work authorization number MRA-047) conducted by Consortium for Electric Reliability Technology Solutions. The information from this project contributes to PIER's Renewable Energy Technologies Program.

For more information about the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-654-4878.

Please cite this report as follows:

Budhraj, Vikram, John Ballance, Jim Dyer, and Fred Mobasheri (Electric Power Group, LLC), Eto, Joseph (Lawrence Berkeley National Laboratory). *Renewable Resource Integration Project – Scoping Study of Strategic Transmission, Operations, and Reliability Issues, PIER Final Project Report*. California Energy Commission, PIER Energy-Related Environmental Research Program. Publication #500-2008-XXX.

Table of Contents

Abstract.....	ix
Executive Summary	11
1.0 Introduction	17
1.1. Research Objective.....	17
2.0 Project Approach.....	19
2.1. California’s Existing Power System	19
2.2. Estimates of Potential Renewable Resources.....	20
2.3. Renewables Integration—Expanding the Existing Transmission Gateway Limits	20
2.4. Expanding the Transmission Grids in the Major Load Centers.....	20
3.0 Project Results.....	21
3.1. Power System Operations and Reliability	21
3.2. Renewables Resource Integration and Operation.....	21
3.3. Renewable Resource Need	22
3.4. Renewables Development—Location and Resource Type	25
3.5. Transmission Gateways Around Load Centers and Capacity for New Renewables to be Delivered to Load Centers.....	26
3.6. Transmission Gateways Serving the Los Angeles Basin Area Served by the California Independent System Operator.....	29
3.7. Transmission Gateway Capacity —Current Plans and Future Needs.....	30
3.8. Transmission Expansion Required within Local Load Areas	31
4.0 Operational Integration Issues	33
4.1. Issues to Be Considered for Renewable Resource Integration.....	33
5.0 Conclusions and Recommendations	37
5.1. Conclusions	37
5.1.1. California’s Renewable Resource Needs and Locations	37
5.1.2. Transmission Gateways and Access to Load Centers	37
5.1.3. Integration of Remote Non-Renewable Resources	37

5.1.4.	Operational Issues.....	37
5.1.5.	Planning and Operating Issues.....	38
5.2.	Recommendations	39
6.0	Benefits to California	41
7.0	References	43
8.0	Glossary.....	45

List of Tables

Table 1. Future Transmission Needs.....	14
Table 2. Qualitative Assessment of Issues and Action Items.....	14
Table 3. Transmission Gateways to California’s Major Load Centers – Illustrative List.....	20
Table 4. Peak Demand and Energy Consumption Forecast.....	22
Table 5. Renewable Energy Production Required for Alternative Renewables Goals	22
Table 6. Renewable Energy and Capacity—2006 Recorded, 2020 Estimated for 33% Renewables	23
Table 7. 2006 Renewable Capacity and Estimated Requirements in 2020 and 2030 (MW)	24
Table 8. 2006 Renewable Energy & Estimated Requirements in 2020 and 2030 (Billion kWh) ...	24
Table 9. Resource Additions and Current Installed Capacity of Renewable Resources.....	26
Table 10. Hypothetical Amount (MW) and Location of Future Renewable Resources.....	26
Table 11. Peak Load Areas Identified in California ISO Study	27
Table 12. Load Areas and Transmission Import Limits	28
Table 13. Los Angeles Basin Area Transmission Gateways for Integrating 20,000 MW of New Renewable Capacity	29
Table 14. Qualitative Assessment of Resource Options on Renewables Integration	38
Table 15. Qualitative Assessment of Issues and Action Items for Renewables Integration.....	38

List of Figures

Figure 1. L.A. Basin Area Transmission Gateways	21
---	----

Abstract

California is on a path to increase usage of renewable resources. The renewable capacity additions that will be needed are 20,000 megawatts (MW) to achieve 33 percent renewables by 2030 and 40,000 MW to achieve 50 percent renewables by 2030. For this scoping study, a mid-range estimate of 30,000 MW is assumed to be needed over the next 20 years.

Renewable resources are typically located in remote locations, not near the load centers. Nearly two-thirds or 20,000 MW of new renewable resources needed are likely to be delivered to Los Angeles Basin transmission gateways. Integration of renewable resources requires interconnection to the power grid, expansion of the transmission system capability between the backbone power grid and transmission gateways, and increase in delivery capacity from transmission gateways to the local load centers.

To scope the transmission, operations, and reliability issues for renewables integration, this research focused on the Los Angeles Basin Area transmission gateways where most of new renewables are likely. Necessary actions for successful renewables integration include:

- Expand Los Angeles Basin Area transmission gateway and nomogram (a graph depicting three curves representing different variables so that a line intersecting all three curves intersects the related values of each variable) limits by 10,000 to 20,000 MW.
- Upgrade local transmission network for deliverability to load centers.
- Secure additional storage, demand management, automatic load control, dynamic pricing, and other resources that meet regulation and ramping needed in real-time operations.
- Enhance local voltage support.
- Expand deliverability from Los Angeles to San Diego and Northern California.

Executive Summary

Introduction

The California Energy Commission, through its Public Interest Energy Research (PIER) Program, has supported a series of studies that, taken together, answer basic technical questions relating to deployment of renewable energy technologies at the scale anticipated to achieve higher levels of renewables. The results reported herein were presented at an Energy Commission staff workshop that was conducted for the *2008 Integrated Energy Policy Report (IEPR) Update*.

In this project, renewable resource needs under different scenarios were estimated. To meet California's goals for expanded use of renewable resources, California must develop and integrate tens of thousands of megawatts (MW) of new renewable generation in the next 20 years and beyond. Renewable generation needs to be located where renewable resources are plentiful. Large-scale development of wind, solar thermal, and geothermal resources will typically be remote from the load centers.

Renewable resources have to be interconnected to the power grid for eventual delivery of power to the load centers. In addition to constructing effective transmission interconnections between the renewable resource development areas and California's high-voltage electrical grid, it will be necessary to expand the transmission system capability between the backbone grid and transmission gateways and from transmission gateways to the local load centers.

Several initiatives are underway that address on integration of renewables, the most notable of which is California's Renewable Energy Transmission Initiative (RETI). RETI's premise is that there must be technically informed and consensus-based coordination between the location of concentrations of renewable energy power plants and the location of transmission corridors within the backbone grid that connect these plants to California load centers. Studies directly supporting RETI address this issue.

This study addresses the issue of capacity needs downstream of the backbone grid. The power resources located within the transmission gateways (referred to as local generation) govern the amount of power that can be imported into the load centers from outside the transmission gateways. A primary criterion is to have adequate transmission and generation to withstand the loss of the largest generating unit plus the next most significant element (generator or transmission line) without overloads or cascading outages. Transmission studies define import limits over single transmission paths and nomograms define limits for combined imports over several transmission paths. Local generation is used to assure voltage adequacy, inertia, and operation within safe operating limits.

Purpose

This *Renewable Resource Integration Project* was to identify and shed light on the most important and strategic transmission operations and reliability issues that will be encountered on the path to meeting California's goals for renewable energy power plant deployment and

interconnection to the state's high voltage transmission system. As nearly two-thirds of the new renewable resources would likely have to be integrated into the California electric grid via the Los Angeles Basin Area, this study assessed the issues that could be faced at Los Angeles Basin Area transmission gateways.

Project Outcomes

The California Renewables Portfolio Standard calls for 20 percent of energy consumption to be supplied from renewables by 2010. Assembly Bill 32 is likely to move California toward greater contributions from renewables. This study examined higher levels of renewables penetration of 33 percent by 2020 and 2030 and 50 percent by 2030. The research reported here showed that starting from a 2006 base and generation mix assumptions detailed below¹:

- Renewable capacity additions of 20,000 MW will be needed by 2020 to reach a 33 percent renewables level.
- Renewable capacity additions of 23,000 MW will be needed by 2030 to meet a 33 percent renewables target and 40,000 MW for a 50 percent target. For this scoping study, a mid-range estimate of 30,000 MW is assumed to be needed over the next 20 years.
- To achieve 33 percent renewables level by 2020, energy production from renewable resources will displace energy presently produced by non-renewable generation. Non-renewable generation will produce 13 percent less energy than in 2008.
- Intermittent wind energy will contribute about 10 percent of total energy requirements in 2020 and nearly 20 percent in 2030.

To meet the need for 30,000 MW of new renewable capacity and scope renewable resource integration issues, development of new renewables is assumed to take place as follows:

- Geothermal—3,500 MW total, with 2,000 MW in the Imperial Valley, 400 MW in Northern California, 100 MW in Randsburg (south of China Lake, California), and 1,000 MW in northern Nevada.
- Biomass—1,500 MW distributed within or near load centers.
- Wind—16,000 MW total, with 6,000 MW in Tehachapi, 2,000 MW in the Imperial Valley, 2,000 MW in San Geronio, 2,000 MW in Northern California, 2,000 MW from the Pacific Northwest, and 2,000 MW from Nevada-Arizona.
- Solar Photovoltaic—2,000 MW distributed within load centers.
- Solar Thermal—7,000 MW total, with 2,500 MW at Mohave, 3,000 MW at Barstow, and 1,500 MW in Central and Northern California.

This distribution was derived based on a review of assessments made by RETI, Energy Commission studies, and other readily available information relating to renewables location.

1. See Section 3.3, Renewable Resource Need.

The above distribution of renewables is one possible scenario that was used for scoping of issues.

Based on the geographic distribution of projected new renewable development, more than two-thirds of the new renewable resources would likely have to be delivered to Los Angeles Basin Area transmission gateways (as defined by the California Independent System Operator [California ISO] *2009 Local Capacity Technical Analysis*²). This means that nearly 20,000 MW of new renewable capacity will have to be integrated into the California electric grid via the Los Angeles Basin Area transmission gateways. Hence, for this scoping study, the Los Angeles Basin Area was analyzed to assess issues that need to be considered for renewable resource integration. While the Los Angeles Basin Area was selected for this scoping study, similar transmission gateway delivery issues can be expected in the other load areas as the reliance on remote renewable generation is increased to meet higher levels of renewables.

Based on the California ISO *2009 Local Capacity Technical Analysis*³ results, also referred to as Local Capacity Requirements studies, there are five local areas which comprise more than 5 percent of the total load. These five areas in total account for approximately 87 percent of the total load. The five areas are:

- Greater Bay Area.
- Greater Fresno Area.
- Los Angeles Basin Area.
- Big Creek/Ventura Area.
- San Diego Area.

For each of the locally constrained resource areas, the transmission lines that form the study boundary and the gateway substations that bound each local area were identified. Based on the line ratings that bound each area, a total import capability can be determined for each load area. The *2009 Local Capacity Technical Analysis* describes the simultaneous import limits across the local area boundary transmission lines, which limit also affects the requirement for local generation. The aggregate import limits of the transmission gateways into each local area are also presented in the California ISO *2009 Local Capacity Technical Analysis*. For the Los Angeles Basin Area served by the California ISO, the aggregated rated capacity of all the transmission gateways is over 23,000 MW, but the aggregated import limit is less than half or 10,642 MW.

2. California Independent System Operator. May 1, 2008. *2009 Local Capacity Technical Analysis – Final Report and Study Results*, [<http://www.caiso.com/1fba/1fbace9b2d170.pdf>]

3. California Independent System Operator. May 1, 2008. *2009 Local Capacity Technical Analysis - Final Report and Study Results*, [<http://www.caiso.com/1fba/1fbace9b2d170.pdf>], [<http://www.caiso.com/1fba/1fbace9b2d170.pdf>].

Conclusions

If two-thirds of the new renewable resources are likely be delivered to Los Angeles Basin Area transmission gateways, nearly 20,000 MW of new renewable capacity would have to be integrated via the Los Angeles Basin Area gateways. Based on forecasts of renewable resource locations, the future transmission needs (beyond Tehachapi and Devers-Palo Verde 2) are shown in Table 1.

Table 1. Future Transmission Needs (Gross Estimates)

Additional MW of Capacity	Location	Resource Type
1,500	Vincent/Antelope Gateway	Wind
4,000	Mirage Gateway	Geothermal and Wind
5,500 – 7,500	Lugo Gateway	Solar thermal and Nevada-Arizona Wind
2,000 – 4,000	Devers Transmission Gateway	Wind

Source: Electric Power Group

Currently, the California ISO experiences many operational issues such as regulation, ramping, and voltage support, with the existing resource portfolio in its control area. These issues will likely worsen with the addition of remote renewables and shutdown of local generation due to air quality and water use constraints unless steps are taken to resolve or mitigate the issues. Most of the issues relate to resource and demand balancing within the control area. Besides the fact that the operational issues can be extremely challenging for the control area operator to manage, the failure to comply with a North American Electric Reliability Corporation Performance Standards could lead to a \$1 million per day penalty.

An assessment of the Los Angeles Basin Area was made to scope the renewable resource integration issues. Table 2 provides a qualitative assessment of issues and the necessary action items to effectively integrate renewables and ensure reliable power system operations.

Table 2. Qualitative Assessment of Issues and Action Items

Issues	Action Items
Add New Renewables	Addition of 20,000 MW of Renewables – Base Case
Transmission Gateway Capacity	Expand by 10,000 to 20,000 MW 5-15 year lead time
Local Network Reinforcements	Upgrade lines, fault current limiters, breakers, remedial action schemes
Capacity Import Limits	Expand by 10,000 to 20,000 MW
Regulation and Ramping	Need additional Regulation & Ramping Utilize storage, demand management, automatic load control, dynamic pricing
Local Voltage Support	Add capacitors and dynamic voltage control devices

Source: Electric Power Group

Recommendations

Meeting higher levels of renewables on a timely basis will require a concerted effort on several fronts:

- The planning and study focus needs to immediately expand from evaluating just the interconnection of remote renewable resources to the grid to delivering the renewable energy all the way to the respective load centers.
- Policy makers need to provide guidance on resource type and location to facilitate timely integration of renewables and support early planning and upgrades of transmission gateway capacity and deliverability to load centers. This effort will be aided by the Renewable Energy Transmission Initiative effort currently underway.
- Transmission owners and the California ISO need to move the planning horizon out to 15–20 years.
 - Define long-term transmission gateway requirements.
 - Define long-term transmission requirements from the gateways into the load centers.
- Transmission owners and the California ISO need to initiate studies (similar to those conducted for Tehachapi) to expand transmission gateways and deliverability into the load centers.
- The California ISO needs to provide utilities and California Public Utility Commission (CPUC) with guidance on resource attributes needed for reliable operation of the power system.
- Transmission requirements for transfer of larger amounts of renewable energy from the Los Angeles Basin to San Diego and Northern California need to be reviewed and upgrades analyzed.

Benefits to California

Carrying out the recommendations from this initial scoping research study will promote integration of renewables to meet California's goals for greater use of renewable resources and reaching higher levels of renewables.

1.0 Introduction

California is on a path to increase utilization of renewable resources to provide for growing electricity needs, to attain fuel diversity for power production, and meet GHG reduction targets. The use of additional renewable resources is in response to the following legislative and policy directives:

- **2002**–Senate Bill (SB) 1078 (Sher, Chapter 516, Statutes of 2002) established a statewide Renewables Portfolio Standard (RPS) of 20% by 2017.
- **2005**–California Public Utilities Commission (CPUC) and California Energy Commission (Energy Commission) adopted the Energy Action Plan II that called for renewable resources to provide 33% of California’s electricity by 2020.
- **2006**–SB 107 (Simitian, Chapter 464, Statutes of 2006) accelerated the 20% RPS target date to 2010.
- **2007**–AB 32 (Núñez, Chapter 488, Statutes of 2006) targets greenhouse gas reduction (GHG), which is likely to require further reliance on renewable resources.
- **U.S. Clean Water Act Section 316(b)** – requires the United States Environmental Protection Agency (U.S. EPA) to ensure that the location, design, construction and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impacts. Actions that will restrict the operation of the existing coastal generating plants are likely to require further reliance on renewable resources.

There are many issues that need to be addressed to assure timely development and integration of renewable resources. Several initiatives are underway that have a bearing on integration of renewables, the most notable of which is California’s Renewable Energy Initiative (RETI).⁴ RETI involves a broad cross section of stakeholders with the goal of identifying and assessing competitive renewable energy zones (CREZs). RETI’s objective is to “identify those CREZs that can be developed in the most cost effective and environmentally benign manner.” This will inform policy makers on resource development location and economics, procurement, transmission planning, transmission corridor designation and generation siting, as well as the California Independent Systems Operator’s (California ISO) generation interconnection process.

1.1. Research Objective

The objective of the *Renewable Resource Integration Project* was to conduct a scoping research assessment of strategic transmission, operations, and reliability issues to meet California’s goals in light of emerging regulatory and policy directives and current electric industry activities such as RETI. The approach and tasks carried out in the research are summarized below:

4. <http://www.energy.ca.gov/reti/>

- Quantify the magnitude of renewable resources needed under different scenarios and time frames.
- Summarize magnitude, type and location of renewable resources likely to be developed to meet California's needs, based on existing Energy Commission studies, RETI, and other data sources.
- Outline transmission interconnection and deliverability requirements for renewables integration.
- Summarize emerging trends that impact renewables integration, including operating limits on existing power plants resulting from once-through cooling and air emission rules.
- Identify and scope issues that impact integration of renewables and how they could be addressed, including nomograms, and local voltage requirements.

2.0 Project Approach

2.1. California's Existing Power System

California's existing power system evolved through integrated resource planning by vertically integrated utilities. Power plants were located near load centers or near sources of fuel. This resulted in gas and nuclear power plants near the major load clusters of San Francisco, Los Angeles County, Orange County, and San Diego. In addition, hydro power plants were built in the Sierras and out-of-state power (coal, nuclear, hydro) was delivered to the load centers via high-voltage transmission interconnections with neighboring states. For the most part, large hydro and pump storage projects and gas-fired generation near load centers provided the following operating attributes:

- Load following.
- Spinning and operating reserve.
- Regulation and ramping.
- Voltage support.
- Inertia.
- Local supply adequacy and reliability.

The transmission system was planned for delivery of local and imported power to loads. Imported power entered the load centers via major transmission gateways. These transmission gateways serve as the entry point for power to California major load centers and are generally 230 kilovolt (kV) or 500 kV substations with the capacity to integrate large amounts of electricity, typically over a thousand megawatts (MWs). Most large-scale renewable resources will be developed outside of the local load centers served by the transmission gateways. Hence, it is important to understand the capacity at each gateway in order to facilitate the integration of renewables.

An illustrative listing of transmission gateways that serve California major load centers as defined by the California Independent System Operator (California ISO) in their studies of local load areas is shown in Table 3.⁵

5. California Independent System Operator. May 1, 2008. *2009 Local Capacity Technical Analysis - Final Report and Results*, [<http://www.caiso.com/1fba/1fbace9b2d170.pdf>],

Table 3. Transmission Gateways to California’s Major Load Centers⁶ – Illustrative List

Major Load Center	Transmission Gateways - Internal	Transmission Gateways - External
San Francisco	Delta, Metcalf, Pittsburg	Moss Landing, Tesla, Vaca Dixon
Los Angeles Basin	Devers, Gould, Mesa, Mira Loma, Rio Hondo, San Onofre	Antelope, Lugo, Palo Verde, Sylmar, San Luis Rey, Talega, Vincent
San Diego	Miguel, San Luis Rey, Talega	Imperial Valley, San Onofre, Tijuana

Source: California ISO. 2009 Local Capacity Technical Analysis – Final Report and Study Results.

2.2. Estimates of Potential Renewable Resources

In order to meet California’s goals for expanded use of renewable resources, California must develop and integrate approximately 30,000 MWs of new renewable generation in the next 20 years. Due to the fact that renewable generation depends upon natural resources for its energy supply, the resources will be developed where the natural resources are most favorable. This will mean that wind, solar thermal, and geothermal resources will be likely developed where their respective natural resources are most plentiful, which is typically not near the load centers. In contrast, biomass and solar photovoltaic may indeed be developed on a distributed basis near the load centers. Forecasts of renewable resource potential by region will be used to estimate a likely scenario of resource development.

2.3. Renewables Integration – Expanding the Existing Transmission Gateway Limits

Renewables resources have to be interconnected to the power grid for eventual delivery of power to the load centers. In addition to constructing effective transmission interconnections between the renewable resource development areas and California’s high-voltage electrical grid, it will be necessary to expand the transmission system capability between the backbone grid transmission gateways and from the transmission gateways to the local load centers. Based on studies already performed by the California ISO, transmission gateways which will need to be expanded were identified. It is important for transmission owners to initiate studies to expand transmission gateways for integration of renewables so that transmission gateways do not become bottlenecks or constraints for timely integration of renewables to meet RPS goals.

2.4. Expanding the Transmission Grids in the Major Load Centers

Based on illustrative case studies performed for the Energy Commission, estimates of internal transmission upgrades that will also be required to accommodate the large expansion of the use of renewable resources are also discussed in this report.

6. Refers to areas served by the California ISO.

3.0 Project Results

3.1. Power System Operations and Reliability

The power resources located within the transmission gateways govern the amount of power that can be imported into the load centers from outside the transmission gateways. Reliability assessments are performed to evaluate the ability to maintain the integrity of the power system and keep the lights on under a variety of operating conditions, without overloading or damaging equipment. A primary criterion is to have adequate transmission and generation to withstand the loss of the largest single risk without overloads or cascading outages.

Transmission studies define import limits over single transmission paths and nomograms for combined imports over several transmission paths. For example, the Southern California Import Transmission (SCIT) nomogram establishes limits on what may be simultaneously imported into Southern California from several interconnections to the east, based on the portfolio of generation resources that are operating within the zone defined by transmission gateways or load centers. The local generation is used to assure voltage adequacy, inertia and operation within safe operating limits.

The development of renewable resources to meet California needs and policy goals, for the most part, will occur remote from the load centers. These renewable resources will need to deliver power to load centers through one or more of California's several transmission gateways. The quantity of renewables that could be integrated at each of the gateways is a function of adequate transmission from renewables to transmission gateways, capacity from gateways to load centers, the mix of resources within the load centers, and the network capacity within the load centers.

3.2. Renewables Resource Integration and Operation

There are several factors that impact integration of renewables into the power grid and operation of the power grid. These factors include:

- Amount of resources to be developed or resource need.
- Location of resources to be developed.
- Type of resources to be developed (defined by the operating characteristics of the resources, such as their daily energy production profiles).
- Interconnection of new renewables with the high voltage grid.
- New transmission or upgrades to move renewable power from the point of interconnection to transmission gateways.
- Upgrades required at and from each transmission gateway to expand deliverability capacity to load centers.

- Impact of likely changes to the current generation portfolio due to environmental constraints, retirements, and unit shutdowns, in particular of generation currently operating within the load centers.

3.3. Renewable Resource Need

In November 2007, the Energy Commission provided the energy and capacity forecasts for 2008, 2013, and 2016.⁷ The forecasts expected energy consumption to increase at 1.29% annually until 2016, and the peak demand to increase at 1.37% annually until 2016. Forecast peak and energy for 2020 and 2030 were estimated by the Electric Power Group assuming the same growth rates, that is, 1.29% and 1.37%, respectively, for energy and capacity, would continue until 2030. The resulting peak and energy forecasts are presented in Table 4.

Table 4. Peak Demand and Energy Consumption Forecast

	2008	2013	2016	2020	2030
Peak Demand (MW)	62,946	67,524	70,174	74,094	84,877
Energy (Billion kWh)	289.0	309.1	320.2	337.0	383.1

Source: California Energy Commission. *California Energy Demand 2008 - 2018: Staff Revised Forecast - Final Staff Report, 2nd Edition*. Forecast values for 2020 and 2030 based on 2008-2016 forecast growth rates

The RPS goal is for 20% of electricity sold to be supplied from renewables by 2010. AB 32⁸ is likely to move California towards greater contributions from renewables. It is also likely that meeting the 20% renewables level will be delayed by several years beyond the current deadline of 2010. The amounts of renewable energy required to meet alternative levels of renewables by 2020 and 2030 are presented in Table 5.

Table 5. Renewable Energy Production Required for Alternative Renewables Goals

Year	Total Annual Energy Consumption In Billion kWh	Renewable Energy Production BkWh		
		20% Renewables	33% Renewables	50% Renewables
2020	337	67	111	169
2030	383	77	126	192

Source: *California Energy Demand 2008 - 2018: Staff Revised Forecast - Final Staff Report, 2nd Edition*. Annual Energy Consumption from Table 2. Renewable Energy Production estimates calculated on 20%, 33% and 50% of Annual Energy Consumption.

The Energy Commission estimated the total renewable capacity requirement to meet the 33% renewables level in 2020 as 26,622 MW.⁹ While there are many other scenarios and forecasts, for

7. California Energy Commission. 2007. [California Energy Demand 2008 - 2018: Staff Revised Forecast - Final Staff Report, 2nd Edition](#). CEC-200-2007-015-SF2.

8. Chapter 488, Statutes of 2006. California Global Warming Solutions Act of 2006.

9. California Energy Commission. 2007. *Integrated Energy Policy Report 2007- Commission Final Report*, Publication Number CEC-100-2007-008-CMF.

the purposes of this study, the Energy Commission report provides a good base line. The 2020 energy was estimated assuming 90% capacity factor for geothermal and biomass, 30% capacity factor for wind and solar, and the same production level from small hydro as recorded in 2006. This resulted in renewable energy production of 111 Billion kilowatt-hours (BkWh) in 2020, or 33% of total energy. The recorded 2006 data and 2020 estimated amounts for 33% renewables for energy and capacity are summarized in Table 6. Hence, compared to 2006 recorded data, 20,301 MW of additional renewable capacity and 80.5 BkWh of additional energy from renewables will be needed to meet the 33% renewables target in 2020.

Table 6. Renewable Energy and Capacity – 2006 Recorded, 2020 Estimated for 33% Renewables

Resource Type	2006 Recorded In-State		2020 Estimates for 33% Renewables		Change	
	Capacity (MW)	Energy Billion kWh	Capacity (MW)	Energy Billion kWh	Capacity (MW)	Energy Billion kWh
Geothermal	1,790	13.4	5,100	40.2	3,310	26.8
Biomass	697	5.8	2,000	15.8	1,303	10.0
Small Hydro	830 est.	5.8	830	5.8	0	0
Wind	2,655	4.9	12,700	33.4	10,045	28.5
Solar	357	0.6	6,000	15.8	5,643	15.2
Total	6,329	30.5	26,630	111	20,301	80.5

Source: 2006 Capacity data from Energy Commission California Power Plant Database; 2006 energy data from Energy Commission 2006 Net System Power Report; 2020 capacity data from Energy Commission Integrated Energy Policy Report 2007 Commission Final Report; Energy based on assumed capacity factors: 90% for geothermal and biomass; 30% for wind and solar.

Renewable energy and capacity requirements for 20% and 33% renewables scenarios in 2020, and 33% and 50% renewables scenarios in 2030 were calculated from the data in Table 4 and the results are presented in Tables 5 and 6. The results presented are computed based on a simple ratio or scaling method, with some adjustment to account for the resource potential of each resource type, to estimate capacity and energy by resource type for different scenarios.

The renewable capacity and energy requirements for different scenarios presented in Tables 7 and 8 have been developed to quantify the approximate amount of renewable energy and capacity required. These approximations are meant to identify issues that need to be considered for renewables integration, including, for example, the need to expand deliverability capacity from transmission gateways to load centers. For the purposes of scoping operational integration issues, such an approximation is adequate.

Table 7. 2006 Renewable Capacity and Estimated Requirements in 2020 and 2030 (MW)

Resource Type	2006	2020		2030	
	Recorded	20% Renewables	33% Renewables	33% Renewables	50% Renewables
Geothermal	1,790	3,091	5,100	5,100	7,725
Biomass	697	1,212	2,000	2,000	3,031
Small Hydro	830 est.	830	830	830	830
Wind	2,655	7,697	12,700	15,084	24,561
Solar	357	3,636	6,000	7,126	10,516
Total	6,329	16,466	26,630	30,140	46,663

Source: 2020 and 2030 capacity estimates scaled from 2020 33% renewables values provided in Energy Commission *Integrated Energy Policy Report 2007 Commission Final Report*. 2030 capacity estimates for wind and solar based on 33% capacity factor (assumed increased capacity factor due to improved technology by 2030).

Table 8. 2006 Renewable Energy & Estimated Requirements in 2020 and 2030 (Billion kWh)

Resource Type	2006	2020		2030	
	Recorded	20% Renewables	33% Renewables	33% Renewables	50% Renewables
Geothermal	13.4	24.4	40.2	40.2	60.9
Biomass	5.8	9.6	15.8	15.8	23.9
Small Hydro	5.8	5.8	5.8	5.8	5.8
Wind	4.9	20.2	33.4	43.6	71.0
Solar	0.6	9.6	15.8	20.6	30.4
Total	30.5	69.6	111	126	192

Source: 2020 and 2030 energy estimates scaled from 2020 33% renewables values in Table 4.

From the analysis presented in Tables 7 and 8, the project team concluded that starting in 2006 renewable capacity additions of approximately 10,000 MW for the 20% renewables and 20,000 MW for the 33% renewables will be needed by 2020. By 2030, capacity additions of 23,000 MW to 40,000 MW will be needed in order to attain the 33% and 50% renewables. Assuming that goals of 33% renewables by 2020 and 50% renewables by 2030 must be met, the project team made the following observations starting from a 2006 base:

- Renewable capacity additions of 20,000 MW will be needed by 2020 and 40,000 MW will be needed by 2030.
- Base load geothermal and biomass capacity will increase to 7,100 MW in 2020 and 10,700 MW in 2030.
- Energy production from renewable resources will displace energy presently produced by non-renewable generation. By 2020, non-renewable generation will produce 13% less energy than in 2008.
- If renewables are non-dispatchable, then load following, regulation, ramping and other operational attributes to run the power system and meet the NERC's mandatory reliability standards will need to be provided by other resources and demand management.

- Intermittent wind energy will contribute about 10% of total energy requirements in 2020 and nearly 20% in 2030.

3.4. Renewables Development—Location and Resource Type

For the purposes of identifying renewable resource integration issues, this analysis indicates that at least 30,000 MW of renewables will need to be integrated by the year 2030. The 30,000 MW represents a mid-range estimate from the 23,000 MW to 40,000 MW required to meet the scenarios of 33% and 50% renewables goals, respectively, by 2030. Development of these renewables will be linked to the geographic regions these where resources are available. Based on a review of Energy Commission Renewable Energy Maps¹⁰ and the RETI Phase 1A Report¹¹, renewables development is likely to be located as follows:

- Geothermal—Imperial Valley, Nevada, and Northern California.
- Biomass—Distributed within load centers.
- Wind—Tehachapi, Palm Springs, Imperial Valley, Northern California, Nevada-Arizona, Wyoming, and Pacific Northwest.
- Solar Photovoltaics—Distributed within load centers.
- Solar Thermal—Barstow, Mohave, and Central California

For this assessment, the location of renewables development is approximated based on data and studies sponsored by the Energy Commission and work currently under way by RETI. To meet the need for 30,000 MW of new renewable capacity, the Electric Power Group assumed the following scenario for development of new renewables:

- Geothermal—3,500 MW total, with 2,000 MW in Imperial Valley, 400 MW in Northern California, 100 MW in Randsburg (South of China Lake, Ca), and 1,000 MW in Northern Nevada.
- Biomass—1,500 MW distributed within or near load centers.
- Wind—16,000 MW total, with 6,000 MW in Tehachapi, 2,000 MW in Imperial Valley, 2,000 MW in San Gorgonio, 2,000 MW in Northern California, 2,000 MW from Pacific Northwest, and 2,000 MW from Nevada-Arizona.
- Solar Photovoltaic—2,000 MW distributed within load centers.
- Solar Thermal—7,000 MW total, with 2,500 MW at Mohave, 3,000 MW at Barstow, and 1,500 MW in Central and Northern California.

Total production from the above resource additions and the currently installed capacity of renewable resources are shown in Table 9 below.

10. California Energy Commission Renewable Energy Maps, <http://www.energy.ca.gov/maps/index.html>

11. Renewable Energy Transmission Initiative Phase 1A Draft Report, March 2008, RETI-1000-2008-001-D

Table 9. Resource Additions and Current Installed Capacity of Renewable Resources

Resource Type	2006 Recorded MW	Additional MW	Total Resources MW	Annual Energy Production BkWh
Geothermal	1,790	3,500	5,290	41.7
Biomass	697	1,500	2,197	17.3
Small Hydro	830 est.	-	830	5.8
Wind	2,655	16,000	18,655	49.0
Solar Photovoltaic	-	2,000	2,000	5.3
Solar Thermal	357	7,000	7,357	19.3
Total	6,329	30,000	36,329	138.4

Sources: 2006 Recorded data from Table 4. New additions from estimates above. Annual energy production based on assumed capacity factors per Table 6.

With the addition of 30,000 MW of new renewables to the recorded 2006 renewables capacity, the annual energy production from these resources was estimated to be 138.4 BkWh based on a 30% capacity factor for wind and solar, and a 90% capacity factor for geothermal and biomass resources.

Based on forecast of total energy consumption of 383.1 BkWh for 2030, the renewable resource production based on Table 9 will be 36.1% of the 2030 energy requirement.

To understand the transmission and operating issues for integrating 30,000 MW of renewables, it is important to define what resources will be developed at what location. Table 10 below presents a hypothetical locational distribution of the renewable resources needed to meet the 33% energy requirement. This is merely one scenario formulated to identify the transmission and operating issues that will need to be considered. Table 10 is not meant to be a forecast, prediction, or recommendation of where renewables will or should develop.

Table 10. Hypothetical Amount (MW) and Location of Future Renewable Resources

Resource Type	No. CA	Central CA	Rands-burg	Teha-chapi	San Gor-gonio	Imperial Valley	Mohave	Bars-tow	Northern Nevada	Nevada-Arizona	Pacific Northwest	Total
Geothermal	400		100			2,000			1,000			3,500
Biomass*												1,500*
Wind	2,000			6,000	2,000	2,000				2,000	2,000	16,000
Solar PV*												2,000*
Solar Thermal		1,500					2,500	3,000				7,000
Total	2,400	1,500	100	6,000	2,000	4,000	2,500	3,000	1,000	2,000	2,000	30,000

Source: Electric Power Group

* Assumed distributed within local load areas

3.5. Transmission Gateways Around Load Centers and Capacity for New Renewables to Be Delivered to Load Centers

The integration of renewables into the power grid involves several elements:

- Interconnection with the grid—generally a radial line(s).
- Upgrades from the interconnection point to transmission gateways around load centers.

- Upgrades from transmission gateways to load centers for delivery of renewable power to loads.
- Operation of the power system consistent with NERC and California ISO reliability standards and providing for needed regulation, ramping, operating reserve, voltage support, local resource adequacy, and other factors.

The California ISO annually performs studies to identify local load centers that are constrained by transmission. In the *2009 Local Capacity Technical Analysis* ten load areas were identified for the 2008 forecast year, as summarized in Table 11.

Table 11. Peak Load Areas Identified in California ISO Study

Local Area	2008 Forecast Peak Load (1 in 10) (MW)	Percent of Total State Load %
Humboldt	199	0.4
North Coast/North Bay	1,495	3.0
Sierra	2,091	4.3
Stockton	1,333	2.7
Greater Bay Area	9,870	20.1
Greater Fresno	3,260	6.6
Kern	1,324	2.7
Los Angeles Basin	19,648	40.0
Big Creek/Ventura	4,911	10.0
San Diego	4,992	10.2
Total	49,123	100.0

Source: California ISO 2009 *Local Capacity Technical Analysis*, Table 6.

Based on the *2009 Local Capacity Technical Analysis*, there are five local areas which comprise at least 5% of the total California ISO service area. These five areas total account for approximately 87% of the total California ISO load. The five areas are:

1. Greater Bay Area.
2. Greater Fresno Area.
3. Los Angeles Basin Area.
4. Big Creek/Ventura Area.
5. San Diego Area.

For each of the locally constrained resource areas, the transmission lines which form the study boundary and the gateway substations that bound each local area are identified. Based on the line ratings that bound each area, a total import capability can be determined for each of the load areas. The *2009 Local Capacity Technical Analysis* describes the simultaneous import limits across the local area boundary transmission lines under the condition of the loss of the largest generating unit plus next most significant element (generator or line), which limit also affects the requirement for local operational generation. The aggregate import limits of the transmission gateways into each of the local areas are determined by subtracting the capacity of

the largest generating unit within the local area from the locally constrained resource amount determined by the studies, then deducting that quantity from the local area load. This remainder represents the maximum aggregate import limit into the local area which can be safely scheduled while protecting the system against the loss of the largest generator within the local area plus the next most significant element, meeting the California ISO's Option 2 criteria¹², and is summarized in Table 12.

Table 12. Load Areas and Transmission Import Limits

Load Area	2008 Load	Aggregate Import Limit of Area Transmission Gateways
Greater Bay Area	9,870	5,995
Greater Fresno	3,260	1,282
Los Angeles Basin	19,648	10,642
Big Creek/Ventura	4,911	2,028
San Diego	4,992	2,500

Source: California ISO. 2009 Local Capacity Technical Analysis, Table 6

In all instances, the actual rated capacity of all the transmission gateways to the load center was greater than the permissible aggregated import limit based on reliability and operating studies. For example, for the Los Angeles Basin Area served by California ISO, the aggregated rated capacity of all the gateways is over 23,000 MW but the aggregated import limit is less than half or 10,642 MW.

The Los Angeles Basin Area represents approximately 40% of the total California ISO load. As illustrated in Table 10, a significant portion of new renewables development is likely to interconnect and deliver power to transmission gateways surrounding the Los Angeles Basin Area. For example, wind resources in Tehachapi, Palm Springs, and Imperial Valley, and even Nevada and Arizona wind are likely to enter the California load centers through transmission gateways surrounding the Los Angeles Basin Area. The same is likely for geothermal resources in Imperial Valley and Nevada, and solar resources north of Lugo Substation (Barstow), and Vincent Substation (Mohave). Hence, for this scoping research assessment, the Los Angeles Basin Area was analyzed to assess issues that need to be considered for renewable resource integration. Similar transmission gateway issues can be expected at the grid's other major load areas as those areas increasingly depend on remotely sited renewable generation to provide their energy supply.

12. California ISO. May 1, 2008. 2009 Local Capacity Technical Analysis Final Report and Study Results, page 15, [<http://www.caiso.com/1fba/1fbace9b2d170.pdf>]. "Option 2 is a service reliability level that reflects generation capacity that is needed to readjust the system to prepare for the loss of a second transmission element (N-1-1) using generation capacity *after* considering all reasonable and feasible operating solutions (including those involving customer load interruption) developed and approved by the CAISO, in consultation with the PTOs. Under this option, there is no expected load interruption to end-use customers under normal or single contingency conditions as the CAISO operators prepare for the second contingency. However, the customer load may be interrupted in the event the second contingency occurs."

3.6. Transmission Gateways Serving the Los Angeles Basin Area Served by the California Independent System Operator

As discussed in Section 3.4, by 2030 the amount of capacity to be integrated ranges from 23,000 MW to 40,000 MW for 33% and 50% renewables, respectively. This assessment is based on a mid-range estimate of 30,000 MW that will have to be integrated over the next 20 years. Based on the estimates in Section 3.4 above, more than two-thirds of the new renewable resources would likely be delivered to Los Angeles Basin Area transmission gateways. This means that nearly 20,000 MW of new renewable capacity will have to be integrated via the Los Angeles Basin Area transmission gateways.

The current import limit of the Los Angeles Basin Area transmission gateways is approximately 10,000 MW. To accommodate an additional 20,000 MW of renewable generation that is likely to be developed or delivered into the Southern California region, the import limits at the Los Angeles Basin transmission gateways will have to increase by 20,000 MW.

The 20,000 MW of renewable resources to be developed will enter the Los Angeles Basin Area load centers through one or more of the transmission gateways listed in Table 13. Also see Figure 1, below.

Table 13. Los Angeles Basin Area Transmission Gateways for Integrating 20,000 MW of New Renewable Capacity

Transmission Gateway	Voltage (kV)
San Diego - San Onofre	230
Lugo – Mira Loma	500
Vincent – Mesa & Vincent – Rio Hondo	230
Antelope - Mesa	230
Palo Verde/Harquahala - Devers	500
Coachella/Ramon - Mirage	230

Source: California ISO. 2008 Year Local Capacity Requirements Study, Big Creek/Ventura Area and the Los Angeles Basin Area.¹³

13. California ISO. March 21, 2007. Year 2008 Local Capacity Requirements Study, Big Creek/Ventura Areas and Los Angeles Basin Areas Presentation, [<http://www.caiso.com/1ba8/1ba87fb845160.pdf>].

the current focus is on renewables development and interconnections, planning for deliverability from transmission gateways to load centers needs to be initiated to prevent delays in integration of renewables. In addition, it will be necessary to expand the capacity for transfer of renewables from the Los Angeles Basin Area gateways to San Diego and Northern California.

3.8. Transmission Expansion Required Within Local Load Areas

In addition to the transmission needed to deliver renewable generation to the grid, and the transmission needed to bring the generation from the grid through the gateway substations into the LCR areas, there are likely to be numerous other internal transmission reinforcements required to strengthen the local area grids. In an Energy Commission report study, the transmission system additions/modifications that would be required should certain amounts of aging power plant generation in the Southern California Edison (SCE) area be retired were discussed.¹⁴ While the premise of the study was the retirement of aging power plants in the SCE area, the results are generally applicable to the scenario of increased use of renewable generation with an attendant reduction in the use of existing aging power plants (even if the aging power plants are assumed to remain operable). The study identified several transmission lines within the SCE system that would need to be upgraded to accommodate additional generation deliveries from the eastern portion of the SCE grid (the location of the bulk of the concentrated solar and geothermal resources), including:

- Chino-Mira Loma #1 230 kV line upgraded.
- Pardee-Moorpark #2 and #3 230 kV lines upgraded.
- Chino-Mira Loma #3 230 kV line reconducted.
- Barre-Ellis 230 kV line reconducted.
- La Fresa-Redondo #1 and #2 lines reconducted.
- Serrano-Villa Park #1 and #2 reconducted.
- Both Pisgah-Lugo 230 kV lines reconducted.
- Antelope-Pardee 230 kV line converted to 500 kV operation.
- Vincent-Santa Clara 230 kV line is looped into Pardee, and the Vincent-Pardee section is converted to 500 kV operation.
- 500 MVAR of reactive support is installed at various substations in the Los Angeles Basin and Ventura County.
- Series capacitors in the Eldorado-Lugo 500 kV line are upgraded.

14. California Energy Commission, A Scenario Analyses of California's Electricity System: Preliminary Results for the 2007 Integrated Energy Policy Report, Second Addendum Draft Report, August 2007, CEC-200-010-AD2-AP.

- The Tehachapi Renewable Transmission Project is completed.
- The Palo Verde/Harquahala-Devers No. 2 500 kV line is completed.

The estimated cost of the upgrades required to accommodate the shifted generation priority (eastern renewable generation in favor of local aged gas-fired generation), expansion of transmission gateway capacity, and the cost of expanded interconnections such as the Tehachapi Renewable Transmission Project and the Palo Verde/Harquahala-Devers No. 2 500 kV line will be substantial. The Tehachapi transmission upgrades are estimated to cost \$1.8 billion for integrating 4,500 MW of wind or approximately \$400/kW. The cost of integrating 20,000 MW of new renewables, assuming the same order of magnitude as Tehachapi, translates to approximately \$8 billion. This requires substantial commitment to plan and implement the needed transmission upgrades for integration of renewables in a timely manner.

While this project team has not yet performed similar assessments for the other local areas, the team expects that significant transmission upgrades will be required in the other local areas in order to accommodate greater dependence on imported (from outside the local area) renewable generation.

While some local area transmission upgrades will certainly be required to accommodate local load growth and increased reliance on generation external to the local area (delivered through the gateway substations and transmission lines), initiatives that accelerate the dependence on external generation, such as programmatic shutdown of coastal generation (for example, U.S. Clean Water Act Section 316(b) requires a mandatory reduction in the use of once-through cooling), or requirements to shift generation from gas-fired sources to renewable sources at rates higher than load growth, will accelerate the need for local transmission upgrades, and incur costs such as those identified in the staff study.

4.0 Operational Integration Issues

4.1. Issues to Be Considered for Renewable Resource Integration

Currently, the California ISO experiences many operational issues such as regulation, ramping, voltage support with the existing resource portfolio in its control area, and these issues will likely worsen with addition of remote renewables and shutdown of local generation due to air quality and water use constraints, unless steps are taken to resolve or mitigate the issues. Most of the issues relate to resource and demand balancing within the control area. According to NERC Standards BAL-001 and BAL-002, the control area's performance shall be in support of "maintaining the Interconnection steady-state frequency within defined limits by balancing real power demand and supply in real-time and to utilize its contingency reserve to balance resources and demand and return Interconnection frequency within defined limits following a reportable disturbance."¹⁵ Besides the fact that the operational issues can be extremely challenging for the control area operator to manage, the failure to comply with a NERC Standard could lead to a \$1 million/per day penalty.

There are four drivers that will accelerate the displacement of the existing fleet of relatively flexible power plants with a replacement fleet of renewables and non-renewable resources with no or very limited operating attributes, which will compound the existing operational issues. The four drivers are:

- Integration of intermittent and non-dispatchable renewables.
- Plant aging and efficiency.
- U.S. Clean Water Act Section 316(b)—mandatory reduction in the use of once-through cooling, which could lead to plant closures that cannot or will not comply.
- California Assembly Bill 32—targets greenhouse gas reduction.

Operational issues are discussed below.

- a. Existing Local Generation—Local capacity resources provide much of the needed regulation, ramping, load following, voltage support and inertia for reliable power system operation. If a significant portion of the existing local generation is shut down, regulation, load following and ramping would have to be provided through other means. Future control area resource attribute requirements need to be defined such that the utilities are procuring the resources with the necessary attributes.
- b. Voltage support—The existing fleet of power plants provide some of the much-needed voltage support in the local load centers. When this fleet is retired or not operating, the transmission grid will require additional transmission investment in hardware such as capacitors and other more sophisticated dynamic voltage support devices.

15. NERC Standard BAL-001-0, Requirement 1 and 2, Standard BAL-002-0, Requirement 4, [http://www.nerc.com/~filez/standards/Reliability_Standards_Regulatory_Approved.html].

- c. Inertia—Inertia is the energy stored in large spinning machines (for example, a generator) that supplies the stored energy during periods of system disturbance (for example, loss of a generator) to arrest the rate at which the system frequency changes. Different types of generation technology provide different levels of inertia. For example, wind provides a low level of inertia compared to a conventional fossil fuel generator. As the electric industry shows a greater dependency on renewable resources and the existing fleet of generating resources is either retired or utilized less, there will be a negative impact on the dynamic response of the California grid, as well as the Western Interconnection. As a result of a reduction in the inertia connected to the grid the Southern California Import Transmission (SCIT) nomogram capacity will be reduced and additional transmission will be needed to make up for such reduction. It is important that inertia requirements are defined in the California resource procurement process.
- d. Minimum Load—When total off-peak power production (after reducing controllable generation to minimum levels) exceeds loads, the situation is referred to as a minimum load issue. High levels of off-peak production (for example, from base load, existing contracts, hydro runoff/run of the river and intermittent energy resources) pose operating challenges for the control area operator, the transmission operator, and the energy supplier, and may require generation curtailment, reduction in imports, increase in off-peak sales, or increase in off-peak loads (pumped storage or retail customer load). Currently, the California ISO is challenged during the spring run-off period and a few other times of the year with minimum load issues. The situation will only worsen as additional base load (for example, geothermal) and intermittent resources are connected to the grid. Currently, California has in excess of 4,000 MW of pumped storage capability that, if coordinated, could be used to mitigate this issue. Also new pumped storage facilities could be constructed. The State should ensure that coordination agreements are developed between owners of pumped storage facilities or encourage the construction of new storage facilities.
- e. Renewable Resource Mix—As mentioned in the beginning of this report, SB 1078 established a statewide RPS of 20% by 2017, which in 2006 was accelerated to 20% RPS by 2010. In addition, the CPUC and Energy Commission, in their Energy Action Plan II, called for renewable resources to provide 33% of California’s electricity by 2020.¹⁶ There is a need to define the needed operating attributes that can be met by use of the different resource technologies such that the system remains operable under all expected conditions, such as minimum load conditions, system disturbances, and rapid demand or resource changes.

16. Energy Commission and California Public Utilities Commission. September 21, 2005. Energy Action Plan II, [http://www.energy.ca.gov/energy_action_plan/2005-09-21_EAP2_FINAL.PDF].

The 2007 *Intermittency Analysis Project (IAP)* final report¹⁷ concluded:

“California can incorporate the amount of renewables based on the Intermittency Analysis Project scenarios, provided appropriate infrastructure, technology, and policies are in place.

Specifically, this successful integration will require:

- Investment in transmission, generation, and operations infrastructure to support the renewable additions.
- Appropriate changes in operations practice, policy and market structure.
- Cooperation among all participants, for example, the California Independent System Operator, investor-owned utilities, renewable generation developers and owners, Non-Federal Energy Regulatory Commission jurisdictional power suppliers, and regulatory bodies.”

The state should ensure that the action items identified in the IAP report are addressed.

- f. Demand Management, Dynamic Pricing, Storage, and Automatic Load Control—As California continues to transition into the implementation phase of higher levels of renewables and a greater portion of consumers’ energy demand is met with renewable resources, we may find that the available resource mix is unable to meet the NERC generation and load balance standards. In anticipation of this potential problem, the State needs to explore options to enhance the use of load for demand management (peak shaving for lack of quick start resources), dynamic pricing, storage, and automatic load control (ALC) to provide certain control area attributes (for example, ramping and regulation).

17. Energy Commission. July 2007. *2007 Intermittency Analysis Project: Final Report, Publication Number CEC-500-2007-081*, [<http://www.energy.ca.gov/2007publications/CEC-500-2007-081/CEC-500-2007-081.PDF>].

5.0 Conclusions and Recommendations

5.1. Conclusions

5.1.1. California's Renewable Resource Needs and Locations

Assuming that goals of 33% renewables by 2020 and 50% renewables by 2030 must be met, the project team made the following key observations starting from a 2006 base:

- Renewable capacity additions of 20,000 MW will be needed by 2020.
- Approximately 47,000 MW of renewable capacity will be needed by 2030.
- For 33% and 50% renewables scenarios for 2030, new renewable capacity of 23,000 to 40,000 MW will be needed, or a mid-range value of 30,000 MW over the next 20–years.
- More than two-thirds of the new renewable resources would likely be delivered to Los Angeles Basin Area transmission gateways. This means that nearly 20,000 MW of new renewable capacity will have to be integrated via the Los Angeles Basin Area transmission gateways.

5.1.2. Transmission Gateways and Access to Load Centers

Renewables resources have to be interconnected to the power grid for eventual delivery of power to the load centers. The integration of renewables into the power grid involves several elements:

- Interconnection with the grid—generally a radial line(s).
- Upgrades from the interconnection point to transmission gateways around load centers.
- Upgrades from transmission gateways to load centers for delivery of renewable power to loads.

5.1.3. Integration of Remote Non-Renewable Resources

The need for integration and transmission upgrades discussed in this report only addresses the needs related to renewable resources. It is very likely that some of the non-renewable resources that will be required to meet the State's increasing load demand, plant retirements and to provide operating flexibility may be located outside the local load centers. The transmission requirements to integrate these non-renewable resource requirements may be in addition to what has been discussed in this report.

5.1.4. Operational Issues

Currently, the California ISO experiences many operational issues with the existing resource portfolio in its control area. Most of the issues are related to resource and demand balancing within the control area, such as over-generation during minimum load conditions, system disturbances (loss of generation), and rapid demand or resource changes. Poor operating performance could lead to non-compliance with NERC's mandatory standards, which could

lead to a \$1 million/per day penalty. As mentioned earlier, there are four drivers that will accelerate the displacement of the existing fleet of relatively flexible power plants with a replacement fleet of renewables and non-renewable resources with no or somewhat limited operating attributes, which will compound the existing operational issues.

5.1.5. *Planning and Operating Issues*

Many of the planning and operating issues can be addressed by choice of resource mix and public policy. A summary qualitative assessment of resource options and their impacts on renewable resource integration is outlined in Table 14.

Table 14. Qualitative Assessment of Resource Options on Renewables Integration

Resource Option	Assessment
Distributed Photovoltaic	Reduces transmission and ramping needs
Distributed Biomass	Reduces transmission needs
Demand management, dynamic pricing	Reduces transmission, regulation and ramping needs
Storage	Provides ramping, regulation, and quick response for reliability management
Solar Thermal	Provides ramping and regulation coincident with load ramps
Peaking Capacity—distributed within load centers	Reduces need to expand transmission gateway capacity. Provides ramping, regulation, and quick response for reliability management
Shut down of local generation	Increases need for transmission gateway capacity, regulation, and ramping

Source: Electric Power Group

Table 15 provides a qualitative assessment of issues and the necessary action items to effectively integrate renewables and ensure reliable power system operations.

Table 15. Qualitative Assessment of Issues and Action Items for Renewables Integration

Issues	Action Items
Add New Renewables	Addition of 20,000 MW of Renewables-Base Case
Transmission Gateway Capacity	Expand by 10,000 to 20,000 MW 5-15 year lead time
Local Network Reinforcements	Upgrade lines, fault current limiters, breakers, remedial action schemes
Nomogram Capacity Import Limits	Expand by 10,000 to 20,000 MW
Regulation and Ramping	Need additional Regulation & Ramping Utilize storage, demand management, automatic load control
Local Voltage Support	Add capacitors and dynamic voltage control devices

Source: Electric Power Group

5.2. Recommendations

Meeting California's renewables targets on a timely basis requires a concerted effort on several fronts:

- a. The planning and study focus needs to immediately expand from evaluating just the interconnection of remote renewable resources to the grid to one of delivering the renewable energy all the way to the respective load centers.
- b. Policy makers need to provide guidance on resource type and location to facilitate timely integration of renewables, and support early planning and upgrades of transmission gateway capacity and deliverability to load centers. This effort will be aided by the RETI effort currently underway.
- c. Transmission owners and California ISO need to move the planning horizon out to 15-20 years.
 - o Define long-term transmission gateway requirements.
 - o Define long-term transmission requirements from the gateways into the load centers.
- d. Transmission owners and California ISO need to initiate studies (similar those conducted for Tehachapi) to expand transmission gateways and beyond into the load centers.
- e. California ISO needs to provide utilities and CPUC with guidance on resource attributes needed for reliable operation of the power system.
- f. Review transmission requirements for transfer of renewable energy from the Los Angeles Basin Area to San Diego and Northern California.

6.0 Benefits to California

Carrying out the recommendations from this initial scoping research study will facilitate integration of renewables to meet California's goals for greater utilization of renewable resources and achieving higher levels of renewables.

7.0 References

Black & Veatch. April 2008. *Renewable Energy Transmission Initiative. Phase 1A Draft Report*, Black & Veatch Project: 149148. Energy Commission Publication Number: RETI-1000-2008-001-D, [<http://www.energy.ca.gov/2008publications/RETI-1000-2008-002/RETI-1000-2008-002-D.PDF>].

California Energy Commission. April, 2007. *2006 Net System Power Report*, CEC-300-2007-007.

California Energy Commission. November 2007. *California Energy Demand 2008 - 2018: Staff Revised Forecast - Final Staff Report, 2nd Edition*. [www.energy.ca.gov/2007publications/CEC-200-2007-015/CEC-200-2007-015-SF2.PDF].

California Energy Commission. May 30, 2008. California Power Plant Database, [<http://www.energy.ca.gov/database/sitingcase/alphabetical.html>].

California Energy Commission. Geothermal Resource Areas Map, [http://www.energy.ca.gov/maps/geothermal_areas.html].

California Energy Commission. December 5, 2007. *Integrated Energy Policy Report, 2007 Summary, Commission Final Report*, CEC-100-2007-008-CMF-ES.

California Energy Commission. Map of Solar Resource Potential in California, [http://www.energy.ca.gov/maps/solar_potential.html].

California Energy Commission. August 2007. *Scenario Analysis of California's Electricity System: Preliminary Results for the 2007 Integrated Energy Policy Report, Addendum 2, Appendices*, CEC-200-2007-010-AD2-AP.

California Energy Commission. Wind Resource Map, [<http://www.energy.ca.gov/maps/wind.html>].

California Energy Commission. December 5, 2007. *Integrated Energy Policy Report, 2007 Summary, Commission Final Report*, CEC-100-2007-008-CMF, [<http://www.energy.ca.gov/2007publications/CEC-100-2007-008/CEC-100-2007-008-CMF.PDF>].

California Independent System Operator. April 10, 2008. *Local Capacity Requirements (LCR) for Year 2009 - Study Results for the Big Creek/Ventura and LA Basin Areas*, [<http://www.caiso.com/1f9d/1f9d890a196a0.pdf>].

California Independent System Operator. *Year 2008 LCR Study, San Diego Area, Summary of Findings*, [<http://www.caiso.com/1ba8/1ba87f5042ad0.pdf>].

California Independent System Operator. March 9, 2007. *2008 Local Capacity Technical Analysis – Report and Study Results*, [<http://www.caiso.com/1b9c/1b9cd9a225830.pdf>].

California Independent System Operator. May 1, 2008. *2009 Local Capacity Technical Analysis – Final Report and Study Results*, [<http://www.caiso.com/1fba/1fbace9b2d170.pdf>].

California Independent System Operator. Operating Procedures, [<http://www.caiso.com/thegrid/operations/opsdoc/index.html>].

California Independent System Operator. March 12, 2007. *Year 2008 Local Capacity Requirements Study, Big Creek/Ventura Area and the LA Basin Area*, [<http://www.caiso.com/1ba8/1ba87fb845160.pdf>].

California Independent System Operator. *Year 2008 Local Capacity Requirements (LCR), Greater Fresno and Kern Areas*, [<http://www.caiso.com/1ba8/1ba87ff44e2c0.pdf>].

California Independent System Operator. *Year 2008 Local Capacity Requirements Study, Greater Bay Area, Summary of Findings*, [<http://www.caiso.com/1ba8/1ba8802c4fcf0.pdf>].

North American Electric Reliability Corporation (NERC). Standard BAL-001-0 and Standard BAL-002-0, [http://www.nerc.com/~filez/standards/Reliability_Standards_Regulatory_Approved.html].

8.0 Glossary

ALC	Automatic Load Control
California ISO	California Independent System Operator
CPUC	California Public Utility Commission
CREZ	Competitive Renewable Energy Zones
Energy Commission	California Energy Commission
GHG	Greenhouse Gas
IAP	Intermittency Analysis Project
IEPR	Integrated Energy Policy Report
LCR	Locally Constrained Resource
MW	Megawatts
NERC	North American Electric Reliability Corporation
PIER	Public Interest Energy Research
RETI	Renewable Energy Transmission Initiative
RPS	Renewable Portfolio Standard
SCE	Southern California Edison
SCIT	Southern California Import Transmission
U.S. EPA	United States Environmental Protection Agency