INPUTS AND ASSUMPTIONS TO 33% RENEWABLES PORTFOLIO STANDARD IMPLEMENTATION ANALYSIS

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UPDATES TO THE JULY 2009 VERSION

Page 5, Paragraph 1: "$52/Megawatt-Hour (MWh)" corrected to "$52/Kilowatt-Year"

Page 11, Table 6: The previous version of this table was truncated in the July 2009 version. This version contains the whole table.

Page 18, Paragraph 1: "92% capacity factor" corrected to "65% capacity factor".

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1. Renewable Resource Supply Data

The following table provides a description of the various resources that E3 draws from to model renewable resource potential within California and around the Western Electricity Coordinating Council (WECC).

Table 1. Description of Data Sources

Data Source	Description
CPUC Energy Division Project Database (ED Database)	The Energy Division maintains a database of renewable energy projects representing approximately 56 Terawatt- Hours (TWh) of electricity that the Investor-Owned Utilities (IOUs) have selected.[1] The projects are in various stages of completion, ranging from projects under negotiation (i.e., short-listed for negotiating a contract by an IOU), to projects that are online. Incorporating short-listed projects distinguishes this study from prior analysis by enabling it to take advantage of information about commercial interest in specific new renewable projects.
Renewable Energy Transmission Initiative (RETI)	The RETI process developed a detailed and comprehensive database of renewable resource potential in California and neighboring states.[2] The RETI analysis provides a stakeholder-vetted engineering assessment of renewable resources at the project level by location and technology type. The RETI dataset relies on proxy projects that are based on expressed commercial interest, it does not include short-listed projects. In addition to renewable resource information, the RETI database categorizes clusters of renewable development into renewable resource zones, which are extremely valuable in the estimates of resource development and transmission need.
GHG Calculator	E3 developed a database of renewable resource potential throughout the WECC as part of its GHG modeling analysis for the California Public Utilities Commission (CPUC), the California Air Resources Board (ARB), and the Energy Commission. The study team relied on the E3 database for information on renewable resources outside of California.[3]
Estimates of distributed renewable energy potential	E3 developed new estimates of the technical potential to connect distributed renewable generation in California. While the distributed solar photovoltaic potential estimates that were developed for this study are very high-level, they are useful for the purpose of testing the benefits and costs of distributed renewables relative to central station power plants to achieve a 33% RPS.

[1] The CPUC maintains a public version of this database at http://www.cpuc.ca.gov/renewables
[2] More information on the Renewable Energy Transmission Initiative process can be found here: http://www.energy.ca.gov/reti/documents/index.html
[3] E3 compiled this database from GIS data from the National Renewable Energy Laboratory, the Energy Information Administration , the Energy Commission, and the Western Governor's Association. More detailed information is available here: http://www.ethree.com/CPUC_GHG_Model.html

E3 takes the resource data for most California renewables from the RETI process, which performed a site-specific audit of renewable energy resources within the state. This analysis provides measures of resource availability, cost, and performance at sites throughout California. E3 supplements the RETI resource assessments with project data from the CPUC Energy Division Project Database, which tracks the results of the IOU renewable solicitations.

For those out-of-state areas that were not looked at in detail during the RETI process, E3 takes resource assessments from the work done in preparing the GHG Calculator. Brief descriptions of E3's method for determining resource potential for each of the different resource types are shown below.

Wind: Wind resource availability is based on data from the National Renewable Energy Laboratory (NREL), which used Geographic Information Systems (GIS) data to estimate the total wind resource availability in the WECC. However, in the 33% RPS Implementation Analysis, E3 updates the method for calculating feasible potential from the total potential identified by NREL. Previously, NREL had filtered according to the ability of the local transmission system to accept more capacity, giving preference to the highest quality wind resources. This resulted in the development of exclusively high quality wind, which E3 found implausible. For the 33% RPS Implementation Analysis, E3 instead applies blanket exclusions to the NREL total wind potential estimates for each class in an attempt to better reflect the actual mix of wind resources that will be available for development in the future. The table below shows the difference between the total NREL resource potential and the amounts resulting from the application of the two different filters (NREL Transmission Filtered Resource Potential and E3 Blanket Exclusion Resource Potential) for Wyoming. Due to the lack of available information on Alberta wind potential, E3 assumes that Alberta has a wind portfolio identical to the closest zone for which data was available, Montana.

Table 2. Wyoming Wind Potential Under Different Filters (Megawatts [MW])

	NREL Total Resource Potential	NREL Transmission-Filtered Resource Potential (% of Total)	E3 Blanket Exclusion Resource Potential (% of Total)
Class 3	361,186	0 (0%)	108,356 (30%)
Class 4	200,335	0 (0%)	60,100 (30%)
Class 5	78,585	77,918 (99%)	23,576 (30%)
Class 6	43,967	43,967 (100%)	8,793 (20%)
Class 7	16,853	16,835 (100%)	1,685 (10%)

Biomass/Biogas: Biomass and biogas estimates in the US portion of the WECC are taken from a 2005 NREL report detailing the nationwide resource potential for biomass.[4] This report provides information on the total theoretical potential available in the western US. E3 uses the ratio of theoretical potential to likely development calculated in the GHG model to adjust this total western US potential downward to a feasible potential estimate. Biomass resources in British Columbia (BC) are taken from information contained in the

[4] NREL, A Geographic Perspective on the Current Biomass Resource Availability in the United States, NREL/TP-560-39181, December 2005.

RETI report, while the Biogas resource estimates are taken from the BC Hydro 2006 Integrated Electricity Plan.[5]

Geothermal: Geothermal resources in Nevada are estimated based on a 2004 study on geothermal resource potential in California and Nevada for the California Energy Commission,[6] which details site-specific resource potential for 43 sites in Nevada. The geothermal resource potential for the remainder of the western US is based on estimates from the Western Governor's Association Clean and Diversified Energy Advisory Committee 2006 Geothermal Task for Report,[7] while estimates for British Columbia are taken from the BC Hydro 2006 Integrated Electricity Plan.[8]

Solar Thermal: Total resource potential for solar thermal (referred to in the CPUC GHG documentation as Concentrating Solar Power) is taken from an NREL GIS dataset[9] that assigns a solar resource class between 1 and 5 to all land area in the WECC, screening out those areas such as federally protected lands and urban settings that would prevent development. E3 assumes that only class 4 and 5 resources will be developed.

Small Hydro: Hydro potential for the western US is taken from the site-specific information contained in Renewable Fuels Module of the EIA's 2007 Annual Energy Outlook.[10] E3 excludes all locations with environmental characteristics that would reduce the likelihood of development, and those locations that would require the construction of new dams. Small hydro potential in British Columbia is taken from a 2007 study for BC Hydro[11] looking at the run-of-river resources available for development. Due to the lack of data, E3 assumes a resource potential of 100 MW of small hydro in Alberta to be consistent with the value used in the GHG Model.

Distributed Renewables: E3 defines distributed renewables as those resources that can be interconnected to the California system without the need for system upgrades or additional backbone transmission lines. The distributed zones in Tables 3, 4, and 5 contain the distributed renewable projects. These projects do not fall into any RETI-identified or GHG Calculator identified resource zones because they are not geographically connected and do not need transmission. They share similar characteristics that allowed them to be grouped together for computational simplicity.

The distributed wind and geothermal projects are sites from the RETI analysis. This dataset also includes two biomass projects that were qualified as distributed biomass. The remaining estimates for the potential amount of distributed biomass and biogas are based on discussions with stakeholders on the developable potential in California.

[5] BC Hydro, "2006 Integrated Electricity Plan (IEP)", March 2006. http://www.bchydro.com/info/iep/iep8970.html.
[6] GeothermEx, Inc., "New Geothermal Site Identification and Qualification", P500-04-051, prepared for CEC, April 2004.
[7] Western Governors' Association (WGA), Clean and Diversified Energy Initiative, "Geothermal Task Force Report," January 2006.
[8] BC Hydro, "2006 Integrated Electricity Plan (IEP)", March 2006. http://www.bchydro.com/info/iep/iep8970.html.
[9] For more information, see http://www.nrel.gov/csp/troughnet/solar_data.html
[10] http://www.eia.doe.gov/oiaf/archive/aeo07/assumption/renewable.html
[11] Kerr Wood Leidal, "Run-of-River Hydroelectric Resource Assessment

The distributed solar resources can be qualified as one of four types of solar photovoltaic (PV) installation: large roof urban PV (larger than 1/3 acre), small roof urban PV, rural ground mounted PV, or large remote ground mounted PV. E3 developed an estimate of the total potential for each type in the service areas of the three large IOUs. Large roof urban PV potential was developed with the help of Black and Veatch, based on GIS data identifying large roofs in urban areas with close proximity to distribution substations. E3 put an upper limit on large roof PV potential at 30% of the peak substation load,[12] and assumed that 67% of that potential would actually be developed. For substations with remaining capacity under the 30% cap after the large roof PV, E3 assumed that small roof PV would fill one-third of that remaining capacity.[13] In rural areas where there were no large roofs, E3 capped ground mounted PV installations at 10% of the substation capacity.[14] In remote areas, E3 assumed that ground mounted two-axis tracking PV installations could be developed above the 30% cap at the local substation level, but assigned a cost penalty of $52/Kilowatt-Year to reflect the transmission upgrades that would be associated with integrating this much capacity.

The following tables show the total resource availability, by zone and resource, for each of the 52 zones modeled in the analysis.

[12] Large Roof PV installations were capped at 30% to reflect compliance with Rule 21 under optimistic assumptions regarding the ability of substations to accept interconnections.

[13] For example, if the large roof PV installations in close proximity of a given substation amounted to 20% of the capacity of the substation assuming one third participation, small roof PV installations would be capped at 3.3% (33%/(30% - 20%)).

[14] Rural PV installations were capped at 10% of substation capacity to reflect compliance with Rule 21. The limits for rural substations were lower because E3 expects that a rural substation will vary more, so its ability to accept interconnections will be reduced.

Table 3. Resources by Type and Zone, MW

	Total Resources by Resource Type (MW)						
	Biogas	Biomass	Geothermal	Hydro - Small	Solar	Wind	*Total*
Alberta	-	-	-	100	-	268,452	*268,552*
Arizona-Southern Nevada	33	43	-	-	157,400	7,812	*165,289*
Baja	-	-	-	-	-	5,420	*5,420*
Barstow	-	-	-	-	1,375	1,115	*2,490*
British Columbia	50	1,520	244	12,344	-	6,630	*20,788*
Carrizo North	-	-	-	4	3,122	-	*3,126*
Carrizo South	-	-	-	-	3,262	-	*3,262*
Colorado	59	44	20	-	18,049	84,242	*102,415*
Cuyama	-	-	-	-	450	-	*450*
Distributed Biogas	249	-	-	-	-	-	*249*
Distributed Biomass	-	162	-	-	-	-	*162*
Distributed CPUC Database	30	226	120	22	127	-	*525*
Distributed Geothermal	-	-	175	-	-	-	*175*
Distributed Solar	-	-	-	-	6,077	-	*6,077*
Distributed Wind	-	-	-	-	-	468	*468*
Fairmont	-	138	-	-	5,707	1,455	*7,300*
Imperial East	-	-	-	-	2,160	123	*2,283*
Imperial North	-	45	1,559	-	1,970	195	*3,769*
Imperial South	-	43	64	-	4,385	46	*4,537*
Inyokern	-	-	-	-	2,601	287	*2,887*
Iron Mountain	-	-	-	-	5,968	62	*6,031*
Kramer	-	-	24	-	7,236	203	*7,463*
Lassen North	-	26	27	-	1,199	1,134	*2,386*
Lassen South	-	-	-	-	1,199	1,000	*2,199*
Montana	5	162	-	36	-	268,452	*268,655*
Mountain Pass	-	-	-	-	3,480	878	*4,359*
Needles	-	-	-	-	1,354	455	*1,808*
New Mexico	18	26	80	-	158,465	93,826	*252,415*
Northeast Nevada	-	-	-	-	-	418	*418*
Northwest	88	1,060	335	231	30,964	24,759	*57,438*
Not Assigned	1	1,210	45	-	2,424	470	*4,149*
Out-of-State Early	-	87	58	15	-	1,902	*2,062*
Out-of-State Late	-	-	-	-	534	1,400	*1,934*
Owens Valley	-	-	35	-	1,419	-	*1,454*
Palm Springs	-	-	-	-	-	806	*806*
Pisgah	-	-	-	-	4,999	1,390	*6,389*
Remote DG	-	-	-	-	9,000	-	*9,000*
Reno Area/Dixie Valley	-	-	1,182	-	7,449	863	*9,493*
Riverside East	-	-	-	-	10,732	-	*10,732*
Round Mountain	-	81	240	-	-	231	*552*
San Bernardino - Baker	-	-	-	-	1,200	-	*1,200*
San Bernardino - Lucerne	-	91	-	-	4,223	641	*4,955*
San Diego North Central	-	20	-	-	-	347	*367*
San Diego South	-	-	-	-	-	903	*903*
Santa Barbara	-	-	-	-	-	515	*515*
Solano	-	-	-	-	-	1,044	*1,044*
South Central Nevada	15	15	108	9	142,613	237	*142,997*
Tehachapi	-	37	-	-	6,179	5,464	*11,680*
Twentynine Palms	-	-	-	-	800	67	*867*
Utah-Southern Idaho	21	181	1,040	220	64,942	12,152	*78,557*
Victorville	-	-	-	-	1,760	436	*2,196*
Wyoming	2	22	-	17	-	202,310	*202,352*
Total	***572***	***5,238***	***5,355***	***12,999***	***674,824***	***998,611***	***1,697,600***

Table 4. Resources by Type and Zone, Gigawatt-hours (GWh)

	Total Resources by Resource Type (GWh)						
	Biogas	Biomass	Geothermal	Hydro - Small	Solar	Wind	*Total*
Alberta	-	-	-	438	-	712,868	*713,306*
Arizona-Southern Nevada	248	302	-	-	354,224	20,052	*374,826*
Baja	-	-	-	-	-	15,718	*15,718*
Barstow	-	-	-	-	3,314	3,015	*6,329*
British Columbia	372	10,653	1,868	49,186	-	18,439	*80,518*
Carrizo North	-	-	-	16	6,741	-	*6,757*
Carrizo South	-	-	-	-	7,054	-	*7,054*
Colorado	442	305	152	-	39,153	220,316	*260,368*
Cuyama	-	-	-	-	998	-	*998*
Distributed Biogas	1,855	-	-	-	-	-	*1,855*
Distributed Biomass	-	1,138	-	-	-	-	*1,138*
Distributed CPUC Database	223	1,582	913	95	305	-	*3,118*
Distributed Geothermal	-	-	1,344	-	-	-	*1,344*
Distributed Solar	-	-	-	-	11,200	-	*11,200*
Distributed Wind	-	-	-	-	-	1,289	*1,289*
Fairmont	-	967	-	-	14,865	4,369	*20,200*
Imperial East	-	-	-	-	5,230	338	*5,568*
Imperial North	-	315	12,064	-	4,659	565	*17,603*
Imperial South	-	299	448	-	10,315	120	*11,182*
Inyokern	-	-	-	-	6,800	716	*7,516*
Iron Mountain	-	-	-	-	14,131	151	*14,282*
Kramer	-	-	168	-	18,481	473	*19,122*
Lassen North	-	182	202	-	2,352	3,049	*5,785*
Lassen South	-	-	-	-	2,502	3,180	*5,682*
Montana	37	1,136	-	177	-	712,868	*714,218*
Mountain Pass	-	-	-	-	8,395	2,445	*10,840*
Needles	-	-	-	-	3,302	1,261	*4,562*
New Mexico	135	180	609	-	345,130	245,360	*591,414*
Northeast Nevada	-	-	-	-	-	1,264	*1,264*
Northwest	656	7,430	2,548	940	47,390	64,968	*123,932*
Not Assigned	4	8,480	355	-	4,211	1,410	*14,460*
Out-of-State Early	-	610	445	66	-	5,497	*6,617*
Out-of-State Late	-	-	-	-	1,304	3,991	*5,295*
Owens Valley	-	-	264	-	3,654	-	*3,918*
Palm Springs	-	-	-	-	-	2,711	*2,711*
Pisgah	-	-	-	-	12,130	3,655	*15,785*
Remote DG	-	-	-	-	19,236	-	*19,236*
Reno Area/Dixie Valley	-	-	8,996	-	16,925	2,593	*28,514*
Riverside East	-	-	-	-	25,689	-	*25,689*
Round Mountain	-	567	1,682	-	-	643	*2,893*
San Bernardino - Baker	-	-	-	-	2,847	-	*2,847*
San Bernardino - Lucerne	-	638	-	-	10,479	1,796	*12,914*
San Diego North Central	-	140	-	-	-	934	*1,074*
San Diego South	-	-	-	-	-	2,583	*2,583*
Santa Barbara	-	-	-	-	-	1,423	*1,423*
Solano	-	-	-	-	-	3,309	*3,309*
South Central Nevada	114	104	820	42	328,012	702	*329,794*
Tehachapi	-	259	-	-	15,753	16,198	*32,209*
Twentynine Palms	-	-	-	-	2,045	194	*2,239*
Utah-Southern Idaho	158	1,270	7,917	907	132,758	31,468	*174,478*
Victorville	-	-	-	-	4,635	1,227	*5,862*
Wyoming	16	154	-	93	-	557,296	*557,559*
Total	***4,260***	***36,711***	***40,795***	***51,960***	***1,486,219***	***2,670,453***	***4,290,398***

2. Zone Definitions

The zones that E3 examines in the 33% RPS Implementation Analysis come primarily from two sources: (1) RETI and (2) the GHG Calculator. The RETI process identifies Competitive Renewable Energy Zones (CREZs) within California and Mexico, representing bundles of renewable resources that can serve as potential origins for large transmission lines carrying renewable energy to load centers. In developing the GHG Calculator, E3 divides the Western Electricity Coordinating Council (WECC) into zones by geography and transmission system topology. These "GHG Calculator zones" form the basis for the classification of resources outside of California.

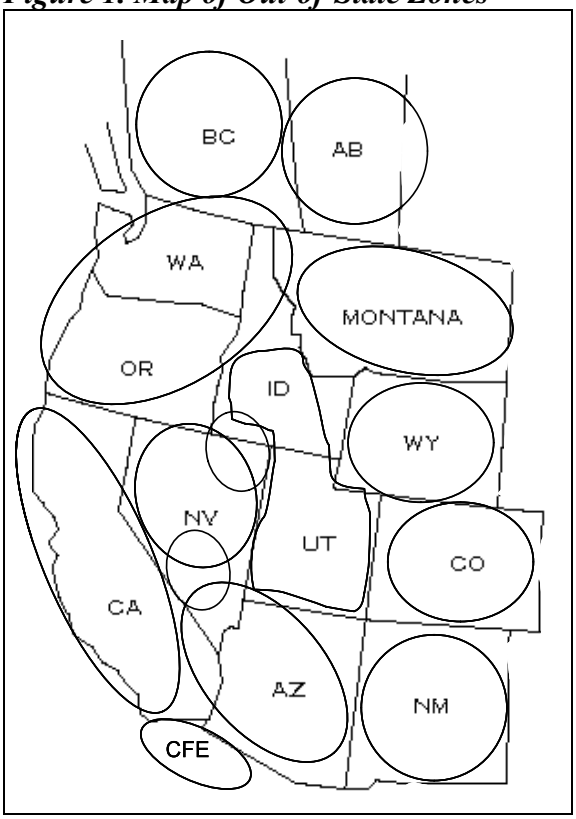
Table 5. Resource Zones

Resource Zone Name	Description or Source
Alberta	GHG Calculator Zone
Arizona – Southern Nevada	GHG Calculator Zone
Baja	RETI CREZ
Barstow	RETI CREZ
British Columbia	Combination of RETI CREZ / GHG Calculator Zone
Carrizo North	RETI CREZ
Carrizo South	RETI CREZ
Colorado	GHG Calculator Zone
Cuyama	RETI CREZ
Distributed Biogas	Biogas resources from RETI and E3 that are assumed to be able to come online without substantial new transmission
Distributed Biomass	Biomass resources from RETI and E3 that are assumed to be able to come online without substantial new transmission
Distributed CPUC Database	Resources of all types from the Energy Division (ED) Database that are assumed to be able to come online without substantial new transmission
Distributed Geothermal	Geothermal resources from RETI and E3 that are assumed to be able to come online without substantial new transmission
Distributed Solar	Solar resources from RETI and E3 that are assumed to be able to come online without substantial new transmission
Distributed Wind	Wind resources from RETI and E3 that are assumed to be able to come online without substantial new transmission
Fairmont	RETI CREZ
Imperial East	RETI CREZ
Imperial North	RETI CREZ
Imperial South	RETI CREZ
Inyokern	RETI CREZ
Iron Mountain	RETI CREZ
Kramer	RETI CREZ
Lassen North	RETI CREZ
Lassen South	RETI CREZ
Montana	GHG Calculator Zone

Mountain Pass	RETI CREZ
Needles	RETI CREZ
NE Nevada	GHG Calculator Zone
New Mexico	GHG Calculator Zone
Northwest	GHG Calculator Zone
Not Assigned	Resources listed in RETI Database that are a) not assigned to a specific geographic zone and b) assumed to require new transmission
Owens Valley	RETI CREZ
Out-of-State Early	Out-of-State resources from ED Database that are either under contract or short-listed and expected to come online in the near term
Out-of-State Late	Out-of-state resources from ED database that are either under contract or short-listed and expected to come online in the long term, plus 1,400 MW of additional out-of-state wind resources assumed to be available to California utilities
Palm Springs	RETI CREZ
Pisgah	RETI CREZ
Remote DG	RETI estimates of PV potential, modified for RPS Calculator
Reno Area / Dixie Valley	GHG Calculator Zone
Riverside East	RETI CREZ
Round Mountain	RETI CREZ
San Bernardino – Baker	RETI CREZ
San Bernardino – Lucerne	RETI CREZ
San Diego North Central	RETI CREZ
San Diego South	RETI CREZ
Santa Barbara	RETI CREZ
Solano	RETI CREZ
South Central Nevada	GHG Calculator Zone
Tehachapi	RETI CREZ
Twentynine Palms	RETI CREZ
Utah – Southern Idaho	GHG Calculator Zone
Victorville	RETI CREZ
Wyoming	GHG Calculator Zone

The following map shows the approximate division of the non-California zones.

Figure 1. Map of Out-of-State Zones[15]



3. Transmission Cost and Sizing Assumptions

The 33% RPS Implementation Analysis looks at the relative values of fixed capacity transmission lines from the various zones. The size of the transmission lines from each zone are determined by the total resource availability in that zone, up to a maximum of 3,000 MW. The lines are modeled to originate at the center of the resource clusters in each zone[16] and terminate at either the Tesla (near Tracy, CA) or Victorville substations, whichever one is closest. These two substations were chosen because they represent transmission hubs in close proximity to major California load centers.

With the exception of the line from British Columbia, which E3 models as a hybrid alternating current (AC) and direct current (DC) line, E3 assumes all lines to be AC lines. The cost of these lines is estimated using a generic line costing model that accounts for both equipment (substations, towers, conductors, etc.) and right-of-way acquisition.[17] The following table details the cost and size of the transmission line that E3 assumes from each zone, as well as the losses associated with that line.

[15] This map is a modified version of the one found in the GHG analysis, produced by E3.
[16] For example, the Wyoming line originates in eastern rather than central Wyoming due to the fact that most wind resources are located in the eastern part of the state.
[17] This transmission costing model was the same as that used for the GHG Calculator. It can be found at http://www.ethree.com/GHG/Transmission_Line_Cost_2007-11-16.xls

Table 6. Transmission Lines

CREZ Name	Assumed Line Capacity (MW)	Overbuild factor	Transmission Line Distance (miles)	Transmission Configuration	Total Cost ($MM 2008)	Incremental Losses	Levelized Cost, $/yr
Alberta	3,000	0%	1,498	500 kV Double Circuit AC Line	$ 7,998	17.2%	$ 997
Arizona-Southern Nevada	1,500	0%	403	500 kV Single Circuit AC Line	$ 2,044	4.6%	$ 255
Baja	1,500	0%	211	500 kV Single Circuit AC Line	$ 1,425	2.4%	$ 178
Barstow	1,800	20%	97	500 kV Single Circuit AC Line	$ 889	1.1%	$ 111
British Columbia	3,900	30%	1,166	500 kV Double Circuit AC Line and 3000 MW DC Line	$ 5,100	13.4%	$ 636
Carrizo North	1,500	0%	174	500 kV Single Circuit AC Line	$ 1,127	2.0%	$ 140
Carrizo South	1,500	0%	237	500 kV Single Circuit AC Line	$ 1,478	2.7%	$ 184
Colorado	3,000	0%	936	500 kV Double Circuit AC Line	$ 5,250	10.8%	$ 654
Cuyama	500	0%	249	230 kV Single Circuit AC Line	$ 1,094	0.5%	$ 136
Distributed Biogas	n/a	0%	n/a	n/a	$ -	0.0%	$ -
Distributed Biomass	n/a	0%	n/a	n/a	$ -	0.0%	$ -
Distributed CPUC Database	n/a	0%	n/a	n/a	$ -	0.0%	$ -
Distributed Geothermal	n/a	0%	n/a	n/a	$ -	0.0%	$ -
Distributed Solar	n/a	0%	n/a	n/a	$ -	0.0%	$ -
Distributed Wind	n/a	0%	n/a	n/a	$ -	0.0%	$ -
Fairmont	1,650	10%	13	500 kV Single Circuit AC Line	$ 549	0.2%	$ 68
Imperial East	1,500	0%	224	500 kV Single Circuit AC Line	$ 1,472	2.6%	$ 183
Imperial North	1,500	0%	151	500 kV Single Circuit AC Line	$ 1,085	1.7%	$ 135
Imperial South	1,500	0%	181	500 kV Single Circuit AC Line	$ 1,199	2.1%	$ 149
Inyokern	1,650	10%	118	500 kV Single Circuit AC Line	$ 948	1.4%	$ 118
Iron Mountain	1,500	0%	170	500 kV Single Circuit AC Line	$ 1,120	2.0%	$ 140
Kramer	1,650	10%	82	500 kV Single Circuit AC Line	$ 823	0.9%	$ 103
Lassen North	1,800	20%	266	500 kV Single Circuit AC Line	$ 1,642	3.1%	$ 205
Lassen South	1,800	20%	344	500 kV Single Circuit AC Line	$ 1,940	4.0%	$ 242
Montana	3,000	0%	1,105	500 kV Double Circuit AC Line	$ 6,090	12.7%	$ 759
Mountain Pass	1,650	10%	194	500 kV Single Circuit AC Line	$ 1,287	2.2%	$ 160
Needles	1,200	20%	395	230 kV Single Circuit AC Line	$ 1,167	1.0%	$ 145
New Mexico	3,000	0%	237	500 kV Double Circuit AC Line	$ 4,522	9.1%	$ 564
Northeast Nevada	500	0%	790	230 kV Double Circuit Line	$ 1,232	0.9%	$ 154
Northwest	1,500	0%	738	500 kV Single Circuit AC Line	$ 3,270	8.5%	$ 408
Not Assigned	n/a	0%	n/a	n/a	$ -	0.0%	$ -
Out-of-State Early	n/a	0%	n/a	n/a	$ -	3.0%	$ -
Out-of-State Late	n/a	0%	n/a	n/a	$ -	3.0%	$ -
Owens Valley	1,500	0%	188	500 kV Single Circuit AC Line	$ 1,211	2.2%	$ 151
Palm Springs	1,000	0%	73	500 kV Single Circuit AC Line	$ 668	0.3%	$ 83
Pisgah	1,800	20%	111	500 kV Single Circuit AC Line	$ 908	1.3%	$ 113
Remote DG	n/a	0%	n/a	n/a	$ -	1.0%	$ -
Reno Area/Dixie Valley	1,500	0%	485	500 kV Single Circuit AC Line	$ 2,332	5.5%	$ 291
Riverside East	3,000	0%	169	500 kV Double Circuit AC Line	$ 1,646	1.9%	$ 205
Round Mountain	500	0%	191	230 kV Single Circuit AC Line	$ 879	0.4%	$ 110
San Bernardino - Baker	1,500	0%	125	500 kV Single Circuit AC Line	$ 1,002	1.4%	$ 125
San Bernardino - Lucerne	1,800	20%	64	500 kV Single Circuit AC Line	$ 732	0.7%	$ 91
San Diego North Central	500	0%	45	230 kV Single Circuit AC Line	$ 585	0.1%	$ 73
San Diego South	1,000	0%	205	230 kV Double Circuit AC Line	$ 1,118	0.9%	$ 139
Santa Barbara	500	0%	280	230 kV Single Circuit AC Line	$ 1,153	0.6%	$ 144
Solano	1,000	0%	20	230 kV Double Circuit AC Line	$ 538	0.1%	$ 67
South Central Nevada	1,650	10%	215	500 kV Single Circuit AC Line	$ 1,345	2.5%	$ 168
Tehachapi	3,000	0%	80	500 kV Double Circuit AC Line	$ 1,252	0.9%	$ 156
Twentynine Palms	1,000	0%	112	230 kV Double Circuit AC Line	$ 766	0.5%	$ 95
Utah-Southern Idaho	1,500	0%	676	500 kV Single Circuit AC Line	$ 2,925	7.8%	$ 365
Victorville	1,650	10%	43	500 kV Single Circuit AC Line	$ 674	0.5%	$ 84
Wyoming	3,000	0%	1,030	500 kV Double Circuit AC Line	$ 5,796	11.8%	$ 722

In zones where there is a relatively balanced mix of solar and wind resources, E3 allows overbuild of resources within that zone up to 20% of the transmission line size. This overbuild reflects the fact that wind and solar resources typically generate at different times. Thus, an area with more diversified resources (for example, see Pisgah, Lassen South, and British Columbia in the table above) can develop resources beyond the assumed capacity of the line from that zone. The overbuild assumed for each zone is shown in the third column in the table above, and reflected in the "Assumed Line Capacity".

4. Cost and Performance Assumptions

E3 derives average cost and performance characteristics from the sites included in the RETI analysis, which provides site-specific cost information for sites within California. Generic cost estimates for installations within California are shown in the table below. All RETI resources, as well as the out-of-state hydro and geothermal resources, have site-specific data which is used when available. The generic cost estimates shown in the table below are applied to all installations for which E3 does not have site-specific data.

The qualifying capacity for wind is based on the 2009 Net Qualifying Capacity (NQC) values used by the California Independent System Operator (CAISO). E3 assumes a qualifying capacity of 20% for wind installations in northern California and 30% for all other areas. Solar PV capacity credit comes from NREL,[18] assuming horizontal placement at 10% penetration for distributed PV. The value for remote zones assumes two-axis tracking at 10% penetration, and as a result, has higher costs (including a cost penalty for transmission upgrades as discussed above) and a higher capacity factor.

Table 7. Generic Resource Costs

Operating Data	Biogas	Biomass	Geothermal	Hydro - Small	Solar PV	Solar Thermal	Wind	Gas CCCT
Nominal Heat Rate	11,566	14,749	-	-	-	-	-	6,924
Capacity Factor	85%	80%	87%	50%	24%	28%	33%	65%
Availability On-Peak (% of Nameplate)	100%	100%	100%	65%	77%	77%	29%	100%
Costs (California Average)								
Installed Capital Costs	$ 3,483	$ 4,951	$ 4,576	$ 3,636	$ 7,065	$ 4,924	$ 2,491	$ 1,249
Variable O&M ($/MWh)	$ 0.014	$ 15.857	$ 40.604	$ 5.129	$ -	$ -	$ -	$ 6.515
Fixed O&M ($/kW-yr.)	$ 160.19	$ 114.11	$ -	$ 19.58	$ 53.70	$ 80.55	$ 73.49	$ 15.17
Fuel Cost ($/MWh)	$ 24.36	$ 44.80	$ -	$ -	$ -	$ -	$ -	$ 71.37
Insurance ($/kW-yr.)	$ 17.42	$ -	$ -	$ 18.18	$ -	$ -	$ -	$ 6.25

E3 also developed regional cost multipliers to reflect differences in the costs of labor and materials across states and provinces. Cost multipliers were developed for both capital and operating and maintenance (O&M) costs, and are based on the State Adjustment factors developed by the U.S. Army Corps of Engineers.[19] These multipliers were then applied to the generic cost estimates to provide state- and resource-specific cost estimates.

[18] Perez, et al., "Update: Effective Load-Carrying Capability of Photovoltaics in the United States," http://www.nrel.gov/pv/pdfs/40068.pdf, p.5

[19] The state-by-state multipliers can be found in table A-3 of this document: http://140.194.76.129/publications/eng-manuals/em1110-2-1304/entire.pdf

Table 8. Regional Cost Multipliers by Region and Resource Type

Regional Cost Multipliers (US average = 1.00)	Biogas	Biomass	Geothermal	Hydro - Small	Solar PV	Solar Thermal	Wind	Gas CT	Fixed O&M
AB	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
AZ	0.975	0.953	0.971	0.950	0.980	0.945	0.977	0.948	0.964
BC	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
CA	1.089	1.170	1.105	1.178	1.073	1.199	1.081	1.186	1.130
CFE	0.955	0.915	0.947	0.911	0.964	0.901	0.959	0.907	0.935
CO	0.990	0.981	0.988	0.980	0.992	0.978	0.991	0.979	0.986
MT	0.980	0.962	0.977	0.960	0.984	0.956	0.982	0.959	0.971
NM	0.970	0.943	0.965	0.941	0.976	0.934	0.973	0.938	0.957
NV	1.045	1.085	1.053	1.089	1.036	1.099	1.041	1.093	1.065
NW	1.040	1.076	1.047	1.079	1.032	1.088	1.036	1.083	1.058
UT	0.980	0.962	0.977	0.960	0.984	0.956	0.982	0.959	0.971
WY	0.955	0.915	0.947	0.911	0.964	0.901	0.959	0.907	0.935

E3 uses a similar method to estimate the performance characteristics of the technologies where site-specific data was unavailable. Data from the RETI sites is rolled up into average performance metrics, which are applied to those resources for which site-specific data was unavailable. For those resources that did not have site-specific capacity factor estimates, E3 assigns a capacity factor based on the resource class. The capacity factor for each resource class (shown below) is based on the average capacity factor among sites in the RETI analysis in that class.

Table 9. Wind Capacity Factors by Resource Class

Wind Resource Class	Capacity Factor
Class 3	29%
Class 4	33%
Class 5	36%
Class 6	39%
Class 7	43%

5. Natural Gas and CO2 Allowance Price Forecasts

The natural gas fuel price forecast that E3 uses for the 33% RPS Implementation Analysis is based on the 2020 Henry Hub Natural Gas Price as traded on NYMEX, while the basis spread for delivery to California comes from the 2009 Market Price Referent (MPR).

The CO2 Price forecast comes from the 2009 MPR Analysis, and is based on an analysis performed by Synapse Energy Economics, Inc.[20]

[20] The paper describing the Synapse analysis can be found here: http://www.synapse-energy.com/Downloads/SynapsePaper.2008-07.0.2008-Carbon-Paper.A0020.pdf

Table 10. Natural Gas and CO2 Price Assumptions

	Nominal (2020) Dollars			2008 Dollars*		
	2020 Base Case	Low Case	High Case	2020 Base Case	Low Case	High Case
Synapse 2020 Nominal CO2 Price Forecast ($/ton)	$ 42.46	$ 15.00	$ 100.00	$ 31.57	$ 11.15	$ 74.36
CO2 Gas Price Adder	$ 2.48	$ 0.88	$ 5.85	$ 1.85	$ 0.65	$ 4.35
Henry Hub Base Nominal Gas Price ($/MMBtu)	$ 8.46	$ 6.00	$ 13.50	$ 6.29	$ 4.46	$ 10.04
Adder for California Delivered to Generator (MPR)	$ 0.37	$ 0.37	$ 0.37	$ 0.28	$ 0.28	$ 0.28
Henry Hub Gas with CO2 Adder ($/MMBtu)	$ 10.94	$ 6.88	$ 19.35	$ 8.14	$ 5.11	$ 14.39
CA Gas Price Forecast w/ CO2, delivered to electric generators ($/MMBtu)	$ 11.32	$ 7.25	$ 19.72	$ 8.42	$ 5.39	$ 14.67
CA Gas Price Forecast w/o CO2, delivered to electric generators ($/MMBtu)	$ 8.83	$ 6.37	$ 13.87	$ 6.57	$ 4.74	$ 10.32

* - Nominal dollars are deflated using a 2.50% annual inflation rate to reach 2008 dollars

6. Financing Assumptions

In order to allow technologies to compete on an even playing field, E3 assumes that all resources are developed by independent power producers (IPPs) using a 20-year financing life as described in Table 10 below. E3 calculates the resulting 20-year levelized $/MWh power purchase agreement (PPA) price at a level that allows the IPP to achieve its target after-tax equity return. E3 assumes that each project is project financed. The solar PV and solar thermal resources have additional equity in their capital structure because without it, the investment tax credit and accelerated tax depreciation result in insufficient operating cash flows to cover debt service in some years.[21] The after-tax equity return for solar resources is lower due to the reduced debt share, which reduces the risk profile of the equity in that project, allowing IPPs to offer equity at a lower rate of return. E3 calculates the debt-equity ratio and return on equity for solar resources such that the pre-tax weighted average cost of capital (WACC) remains roughly constant across resources. The relevant financial assumptions for solar, non-solar, and transmission financing are shown in the table below.

[21] E3 assumed that IPPs would require a debt service coverage ratio of approximately 1.5.

Table 11. Financing Assumptions[22]

	IPP Financing Assumptions (Non-Solar)	IPP Financing Assumptions (Solar)	Transmission Financing Assumptions
All-In Tax Rate	41%	41%	41%
Economic Life (Years)	20	20	40
Debt Life (Years)	20	20	40
After-tax Equity Return	15.29%	13.25%	10.78%
Equity Share in Capital Structure	40%	55%	55%
Debt Share in Capital Structure	60%	45%	45%
Cost of Debt	7.27%	7.27%	5.96%
Pre-tax nominal WACC	10.48%	10.56%	8.63%
After-tax nominal WACC	8.70%	9.23%	7.54%

E3 assumes that existing federal tax incentives will be in place in 2020. Biomass, geothermal, and small hydro resources receive a production tax credit (PTC) of $0.01/kWh (in 2008 dollars), while biogas and wind resources receive a PTC of $0.02/kWh. Solar PV and solar thermal resources receive an investment tax credit of 30%, though E3 assumes that only 95% of the capital cost will be eligible to receive that credit. Black and Veatch ignored state tax incentives in developing their costs estimates.

Property tax was included in the fixed O&M estimates for renewable resources in the Black and Veatch analysis. E3 included a 1% property tax for solar photovoltaic installations.

E3 models geothermal, solar PV, solar thermal, and wind resources as eligible for the Modified Accelerated Cost Recovery System (MACRS) tax depreciation over a five year period. This means that for tax purposes, their cost is depreciated over five years instead of the 20-year assumption used for the remaining resources.

7. Calculation of RPS Need

For California and each of out of state zone included in the analysis, E3 calculates an RPS Need that represents the amount of renewable energy,[23] above existing levels, that each zone must procure to meet applicable standards. E3 takes the requirements in each zone from existing legislation, aggregating requirements for zones that span multiple state jurisdictions. For zones with a standard that goes into effect later than 2020, E3 estimates the need in 2020 based on a straight line interpolation between existing levels of renewables and targets in the binding years. For those zones that do not currently have a Renewable Portfolio Standard or similar legislative requirement, E3 assumes a minimum 5% requirement in 2020. The BC Energy Plan calls for all

[22] Assumptions on the rates of return for equity and debt are taken from the "2008 Capitalization Rate Study" performed by the California State Board of Equalization, found at http://www.boe.ca.gov/proptaxes/pdf/2008capratestudy.pdf. IOU financing parameters are taken from the GHG Model. The Debt-to-Equity ratios were developed based on the GHG model, and adjusted to reflect the changing economic conditions.

[23] "Renewable energy" as defined here includes biogas, biomass, geothermal, small hydro (<30 MW), solar PV, solar thermal, and wind resources.

new electricity projects in British Columbia to have zero net greenhouse gas emissions. To implement this, E3 removes all fossil fuel resources from the British Columbia zone supply curve, but allows BC to develop large hydro resources to meet load growth.

E3 bases the projected California retail sales in 2020 on the growth rates from the 2007 Energy Commission load forecast,[24] which does not include the water agencies (as they are not covered by the 33% RPS requirements). E3 takes the existing generation claimed from renewables from the 2007 CEC Net System Power report.[25] In 2007, California utilities claimed 27,063 GWh from renewables in the WECC, which E3 assumes will be available in 2020. The table below shows the calculation through which the need for renewables was determined for three different load cases. The load reductions in the "Low-Load Sensitivity" are based on the "Aggressive Policy" case in the GHG Model and the joint Energy Commission/CPUC Final Decision on Greenhouse Gas Regulatory Strategies.[26]

Table 12. Calculation of RPS Need

	20% Reference Case (GWh)	33% Reference Case (GWh)	Low-Load Sensitivity (GWh)
2020 Base Retail Sales	308,220	308,220	308,220
- Energy Efficiency			(18,919)
- Rooftop PV			(3,127)
- On-Site CHP			(9,771)
2020 Final Retail Sales	308,220	308,220	276,403
RPS Requirement	61,644	101,713	91,213
2007 RPS Eligible Resources	27,063	27,063	27,063
2020 RPS Need	**34,581**	**74,650**	**64,150**

The RPS Need calculated by E3 for the 33% RPS Implementation Analysis differs from the comparable "Net Short Calculation" developed by Black and Veatch for the RETI Phase 1B report.[27] E3 and Black and Veatch used different methods for calculating the RPS Need (Net Short amount), but the biggest difference is the amount of energy that each analysis assumes available from RPS resources in 2007. The RETI Process assumed almost 13,000 GWh more from existing renewables, accounting for most of the difference between the two need calculations. RETI also assumed 4,200 MW of solar PV resources would be installed by 2020 as part of the California Solar Initiative/Go Solar California program with a capacity factor of 20%, which reduces the retail sales by 7,358 GWh and the Net Short calculation by 2,428 GWh.

[24] California Energy Commission, "California Energy Demand 2008 – 2018 Staff Revised Forecast," CEC-200-2007-015-SF2, November 2007.
[25] California Energy Commission, "2007 Net System Power Report," http://www.energy.ca.gov/2008publications/CEC-200-2008-002/CEC-200-2008-002.PDF, Table A-3.
[26] A more complete description of the E3 GHG "Aggressive Policy" case can be found at http://www.ethree.com/GHG/7%202020%20Base%20Case%20Input%20Summary%20v4.doc or in CPUC Decision 08-10-037.
[27] The description of the calculation used in the RETI Phase 1B report can be found at http://www.energy.ca.gov/2008publications/RETI-1000-2008-003/RETI-1000-2008-003-F.PDF

Table 13. Comparison of RPS Need Calculation from the 33% RPS Implementation Analysis and the Net Short Calculation from RETI

	33% Reference Case (GWh)	RETI Phase 1B Net Short Calculation
2020 Total Consumption		334,169
- Wholesale Consumption		(12,299)
- Self-Generation (Non-PV)		(12,538)
- Self Generation (PV)*		(7,358)
2020 Final Retail Sales	308,220	301,974
33% RPS Requirement	101,713	99,651
2007 RPS Eligible Resources	27,063	39,941
2020 RPS Need	**74,650**	**59,710**

*** The RETI Phase 1B Report assumes the installation of 4,200 MW of Solar PV with a capacity factor of 20% by 2020**

8. Assumptions Regarding OTC Generation and Fossil Retirements

The California State Water Board has determined that generators employing Once-Through Cooling[28] ("OTC Generators") need to be shut down or repowered as non-OTC generators to continue operating, to prevent further damage to marine life. Since the rules were not yet developed when this analysis took place, E3 had to make judgments about the likelihood that a given OTC generator would be shut down, repowered, or allowed to continue operating.

E3 uses a list of OTC generators available from the CAISO[29] to determine which generators will be available in 2020, whether as a result of continued operation for reliability concerns or as a result of repowering. These determinations are based on a review of the capacity factor of the plants, their age, and whether the units were necessary to maintain local reliability. All units that were retired or repowered were assumed to do so between 2011 and 2019. The table below lists the OTC generating units in California, the capacity retired at each plant, and whether any of that capacity was repowered as non-OTC generation.

[28] From the CPUC Report "Potential Impacts of the South Coast Air Quality Management District Air Credit Limitations and Once-Through Cooling Mitigation on Southern California's Electricity System": "Once-through cooling is a technology that uses seawater to cool and re-condense superheated steam after it has been used to generate power and has significant impacts on marine organisms and ocean habitat."

[29] "Generating Units in CAISO Relying on Once-Through-Cooling," available at http://www.caiso.com/208b/208b8b2f329d0.pdf

Table 14. Treatment of OTC Generators

	Total Nameplate Capacity (MW)	Capacity Factor	Retired Capacity (MW)	Repower or retrofit as CCGT (MW)	Repower or retrofit as CT (MW)	Retirement Date
Alamitos 1&2	350	3%	350			2016
Alamitos 3&4	668	13%	668			2016
Alamitos 5&6	992	10%	992			2019
Contra Costa	680	3%	680		600	2019
Diablo	2,240	95%	-			
El Segundo 1&2	-	0%	-		550	2015
El Segundo 3&4	670	11%	-			
Encina 1-5	929	15%	550		550	2016
Harbor	240	10%	-			
Haynes 1&2	444	10%	-			
Haynes 3&4	444	10%	-			
Haynes 5&6	682	10%	-			
Haynes 9&10	575	10%	-			
Humboldt Bay	105	46%	105		163	2011
Huntington	880	15%	-			
Mandalay	430	9%	-			
Morro	673	7%	673			2018
Moss 1-4	1,020	57%	1,020	1,020		2014
Moss 6&7	1,510	17%	-			
Ormond	1,516	3%	-			
Pittsburg	1,311	3%	682			2016
Portrero	207	29%	207			2012
Redondo 5&6	350	2%	-			
Redondo 7&8	963	7%	-			
Scattergood	803	10%	-			
SONGS 2	1,123	68%	-			
SONGS 3	1,109	69%	-			
South Bay	690	17%	690			2014
Total	***21,604***		***6,617***	***1,020***	***1,863***	

9. Energy and Capacity Balancing

Once the model selects a portfolio of renewable resources to meet the 33% RPS goal in 2020, it checks to ensure that there is sufficient energy and capacity in each of four time periods, low-load and high-load hours in both the summer and winter. The model first balances the energy in each time period by adding sufficient Combined Cycle Gas Turbines (CCGTs) to ensure the capability to meet energy demand in the time period during which there is the largest shortfall. CCGTs are assumed to operate at a 65% capacity factor.

Table 15. Sample Energy Balancing Calculation, 33% RPS Reference Case

Conventional Generation Added for Energy Balancing	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Required net additions for energy relative to 2008 Baseline (GWh)	-	3,607	7,258	10,953	14,693	18,477	22,307	26,184	30,107	34,078	38,096	42,163	46,280
Energy from New Renewable Generators (GWh)	-	-	6,424	13,312	16,430	35,661	35,661	35,661	48,325	48,325	54,269	59,800	73,637
Net Energy Required (GWh)	-	3,607	834	(2,359)	(1,737)	(17,184)	(13,354)	(9,477)	(18,218)	(14,247)	(16,172)	(17,636)	(27,357)
Cumulative CCGTs added for balancing (MW)	-	449	449	449	449	449	449	449	449	449	449	449	449

Once the model calculates the number of CCGTs required to meet energy needs, it checks to ensure that there is sufficient capacity to meet peak demand. A capacity shortfall is remedied by the addition of Gas Combustion Turbines (CTs) sufficient to meet peak demand plus a 17% capacity reserve margin.

Table 16. Sample Capacity Balancing Calculation, 33% RPS Reference Case

Conventional Generation Added for Capacity Balancing	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Required additions in dependable capacity (MW)	-	962	1,936	3,028	4,235	5,248	7,984	9,023	12,326	13,393	15,146	17,913	19,022
Dependable Capacity from New Renewable Generators (MW)	-	-	726	2,787	3,273	5,760	5,760	5,760	7,264	7,264	8,536	9,935	13,024
Capacity added from OTC Repowering (MW)	-	-	-	163	163	163	1,183	1,733	2,283	2,283	2,283	2,883	2,883
Capacity added from Energy Balancing (MW)	-	449	449	449	449	449	449	449	449	449	449	449	449
Cumulative CTs added for balancing (MW)	-	513	762	762	762	762	762	1,082	2,331	3,397	3,878	4,646	4,646

The model requires the California system to be balanced in every year between 2008 and 2020, and assumes that once built, balancing resources are available (and incurring costs) for the lifetime of the analysis.