6. Analysis Using the Elfin Model

Calculations behind the capital cost and profitability curves do not take into account some interactions that Elfin simulates. Two of the factors that simple levelized cost analyses ignore are: (1) the effect of wind generation on pool prices, and (2) timing decisions about when to build. More accurate analysis is possible by incorporating the cost and wind resource data directly in the Elfin model and actually simulating the capacity expansion and dispatch patterns through time.

Implementation

As described above, cost, performance, and potential were estimated for the 36 CEC sites. Ultimately, each of the sites was entered into the Berkeley Lab's Elfin data set of the California power market post 2005. The existing generation capacities in Altamont Pass, Solano Hills, Tehachapi Pass, Pacheco Pass, and San Gorgonio are deducted from the potential capacity at these sites.

Each of the sites is characterized by a development cost, a maximum capacity and rate of development, and a description of the wind resource by season and time period. Appendix B shows an example data set for one site. A prototypical wind farm of 50 MW was used. Many of the locations can accommodate several of these 50-MW facilities.

Results

Previous Results with Generic Wind Resources

In previous Berkeley Lab studies, a generic wind farm was used in Elfin to model all the California wind potential (Marnay et al. 1998). In a best-guess scenario where the gas prices increase (in real terms) at a rate of 1.5 %/a, wind capital cost declines at a rate of 1.15 %/a, no wind development and generation occurs, as shown by Figures 21 and 22 respectively. Results of an Elfin run under favorable conditions (where the natural gas prices increase by 3 %/a) for wind development are shown in Figures 23 and 24. Clearly, this scenario does not represent a conventional wisdom future, but rather one contrived to result in extensive wind development. The limitations of this approach are clearly evident in Figure 23. After 2017, wind becomes cheaper than repowers under the assumptions of this simulation, and in fact becomes the only technology built thereafter. Clearly, this result is unrealistic. While some wind capacity may be available at the assumed generic cost, this resource would quickly become exhausted and development would necessarily move to less desirable, more costly sites. In any case, the total installed capacity chosen by the Elfin model by 2030 probably exceeds reasonable estimates of the total wind resources of the state at prices within reason.

Figure 21. Generation Expansion with Generic Wind Resources: Best-Guess Scenario

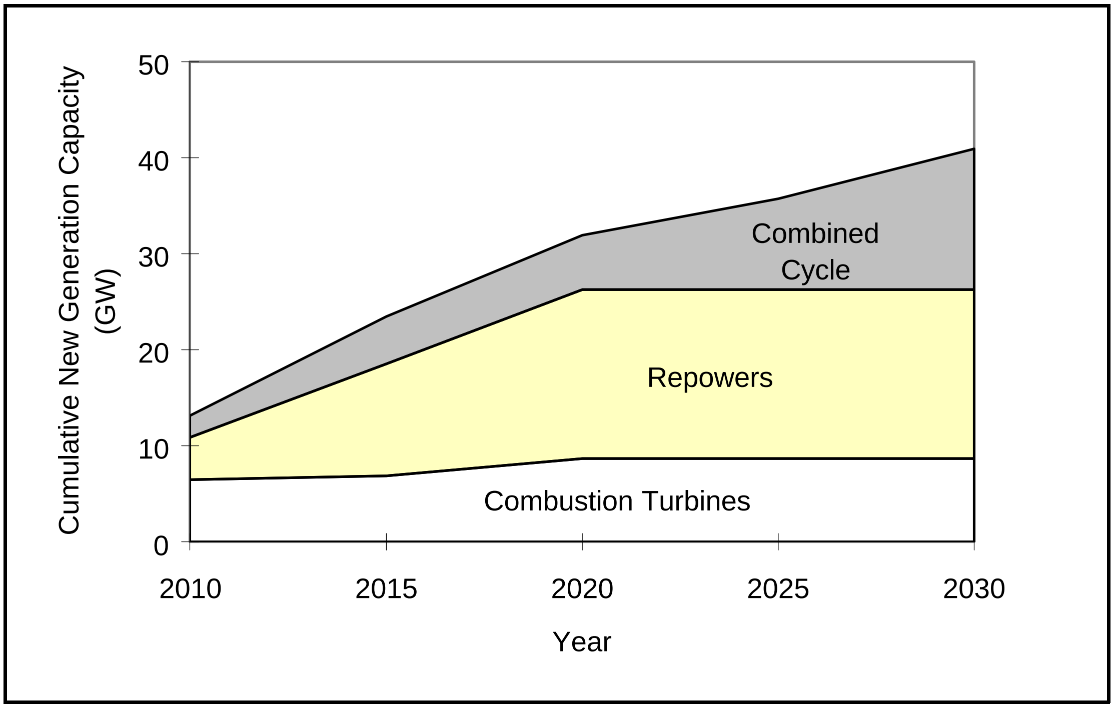


Figure 22. Generation from New Facilities with Generic Wind Resources: Best-Guess Scenario

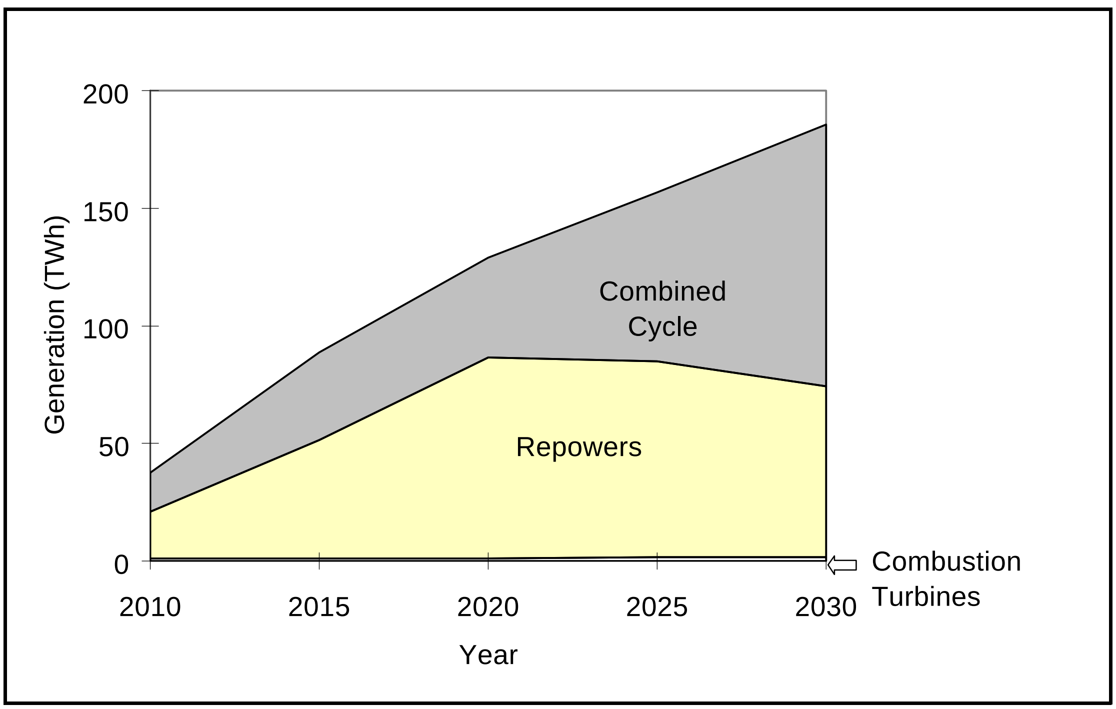


Figure 23. Generation Expansion with Generic Wind Resources: High Gas Price Scenario

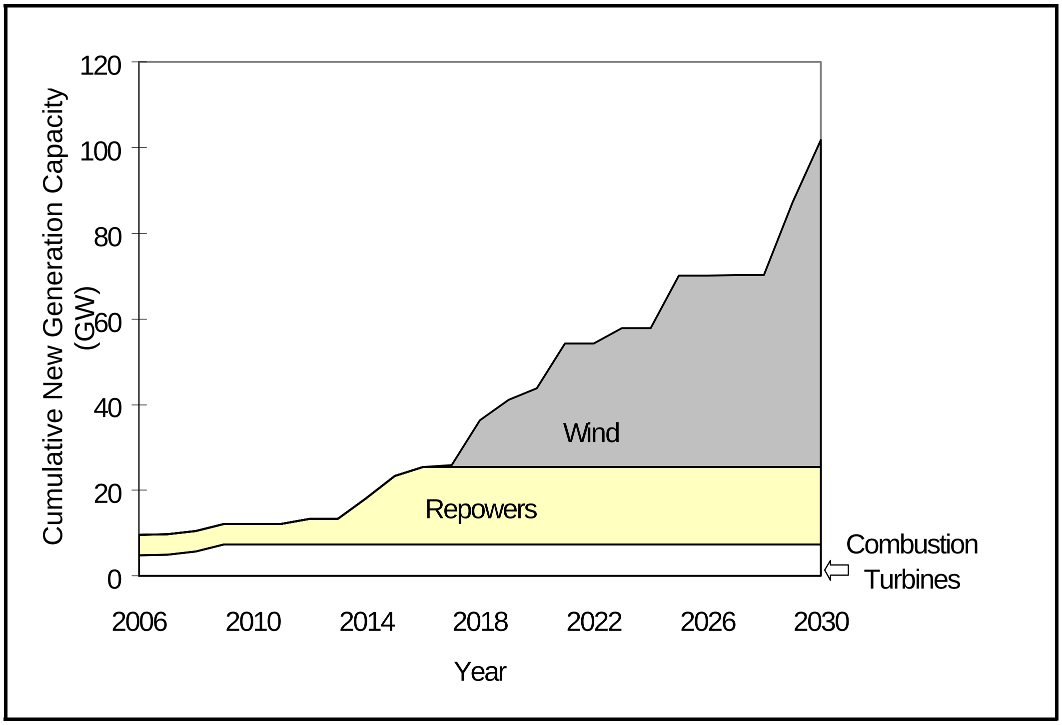
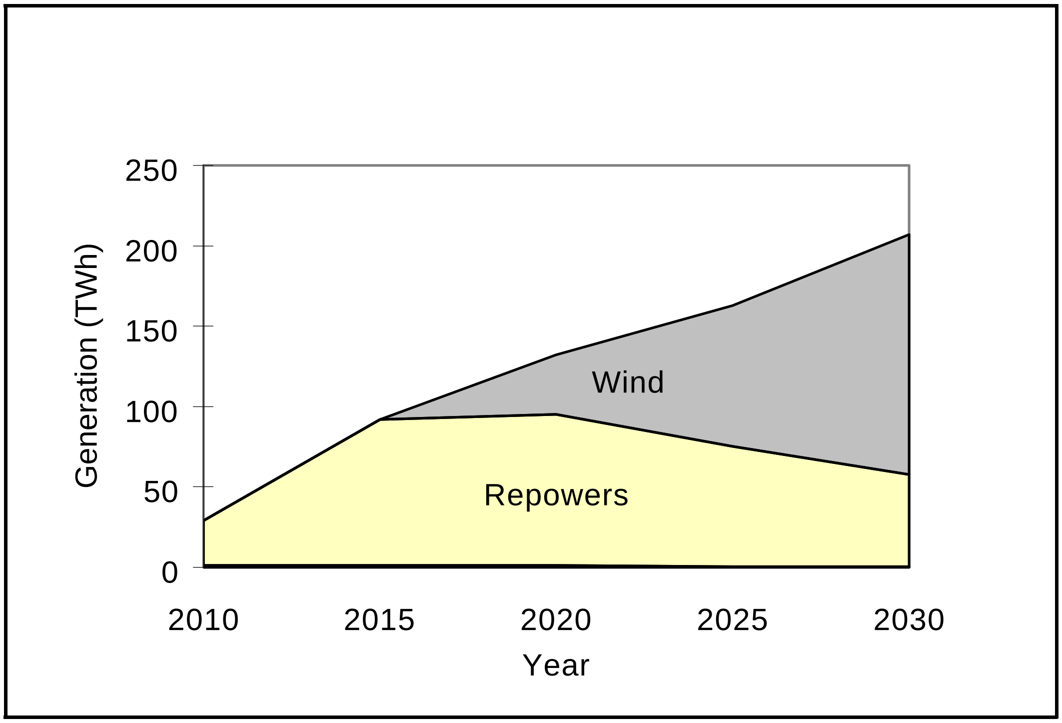


Figure 24. Generation from New Facilities with Generic Wind Resources: High Gas Price Scenario



Current Results with Actual Wind Resources

With the detailed representation of the wind sites developed here incorporated into the Elfin model, generation expansion evolves as shown in Figure 25. Each stripe within the area marked "wind" represents one of the 36 sites. A major share of the total resource is profitable in 2006. In later years, some of the less favorable sites become profitable and wind capacity expands. However, the limit of wind capacity as specified in the input data is never reached, showing that under the assumption of the simulation, an economic result has been found. By the year 2010, 4.6 GW of wind capacity is developed, and this figure increases to 7.4 GW by the year 2030. Figure 26 presents the generation for this scenario in which wind generation from new wind resources reaches 62 TWh by the year 2030.

Figure 25. Generation Expansion with Actual Resources: Best-Guess Scenario

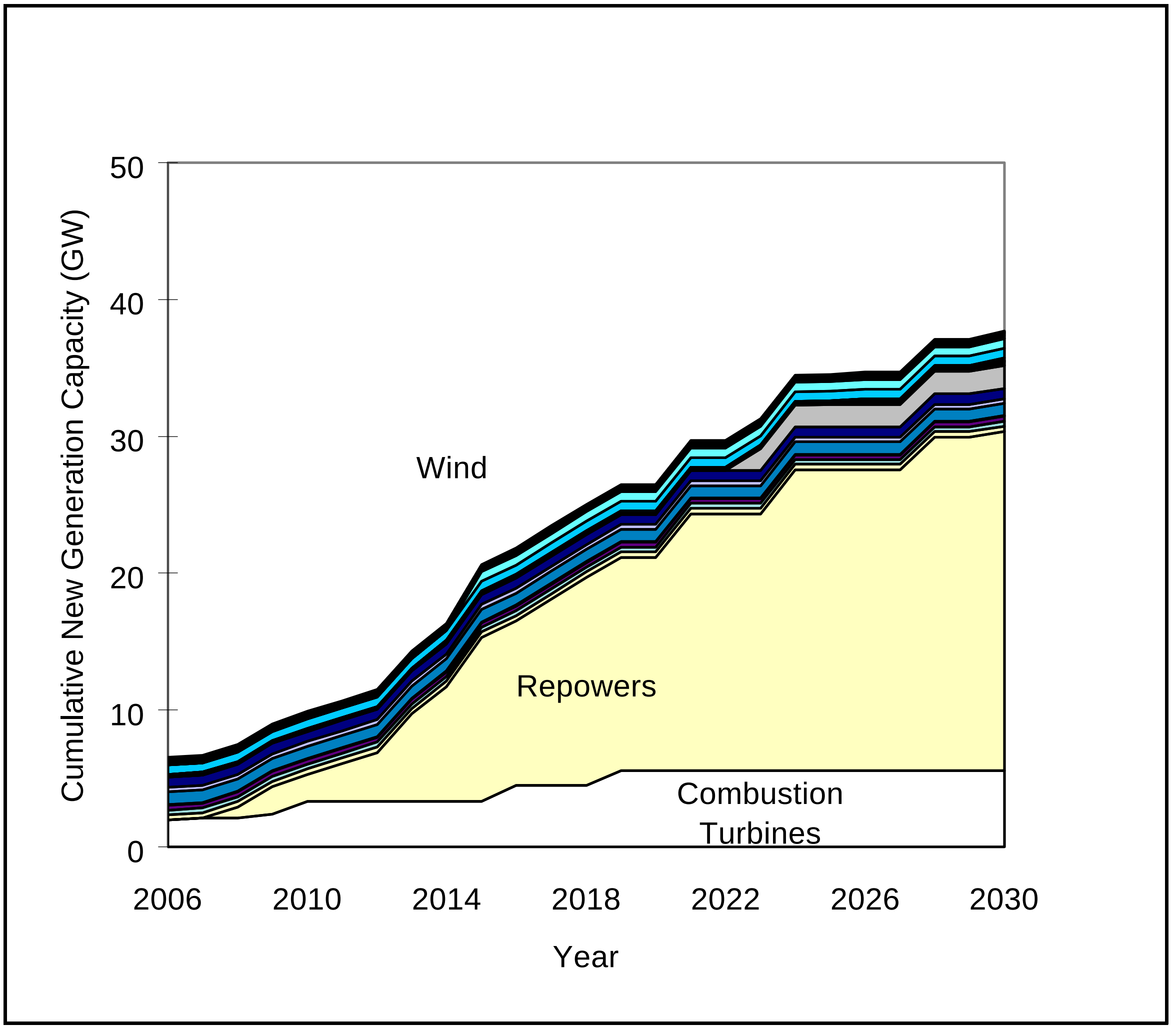
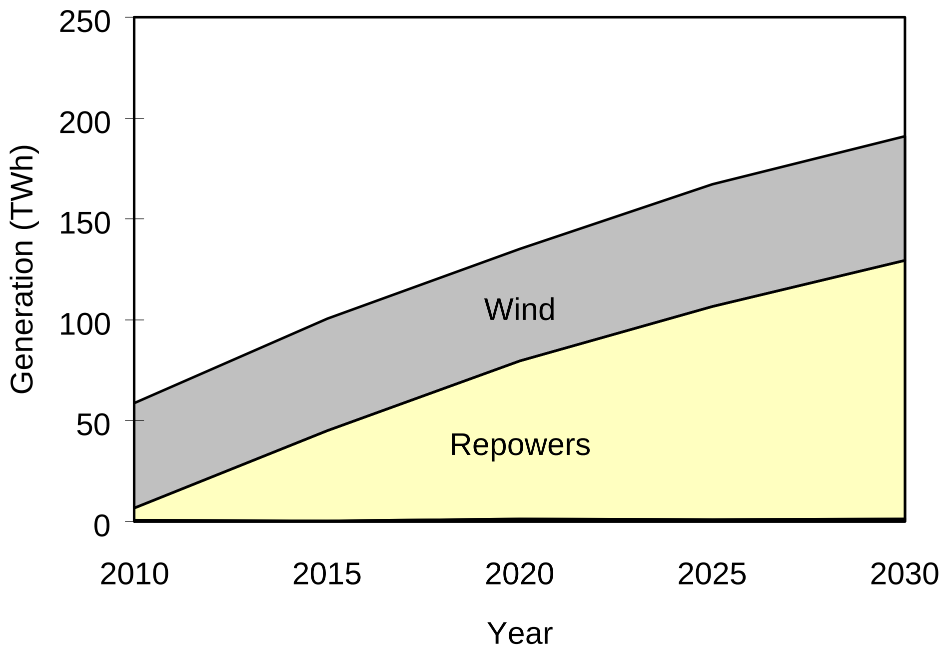


Figure 26. Generation from New Facilities with Actual Wind Resources: Best-Guess Case



The sensitivity of these results to future natural gas prices is also studied. In the best guess scenario, gas prices increase by 1.5 %/a, while under high and low gas price scenarios, natural gas prices increase by zero and three percent, respectively. The results for the low gas price scenario is presented in Figures 27 and 28. The results for the high gas price scenario is presented in Figures 29 and 30. It should be noted that there is not much difference between the best guess and the high gas price scenarios, while in the low gas price scenario, by the year 2030, about 30 percent less wind capacity is developed compared to that in the best-guess scenario. That gap is filled with combined-cycle generators.

Figure 27. Generation Expansion with Actual Wind Resources: Low Gas Price Scenario

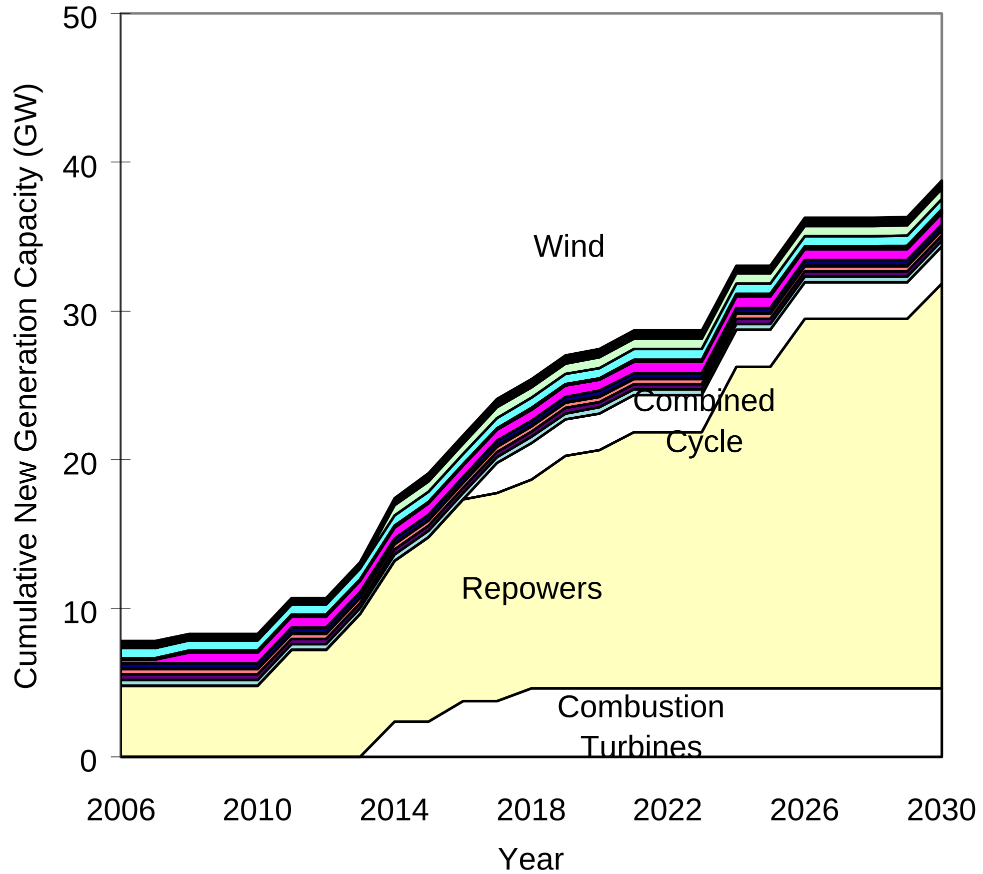


Figure 28. Generation from New Facilities with Actual Wind Resources: Low Gas Price Scenario

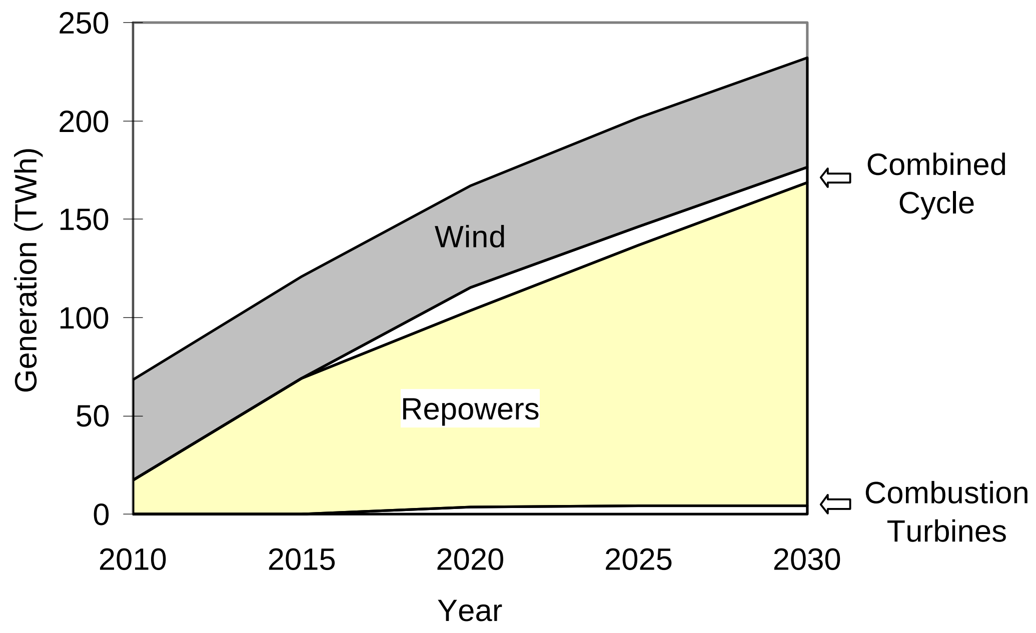


Figure 29. Generation Expansion with Actual Wind Resources: High Gas Price Scenario

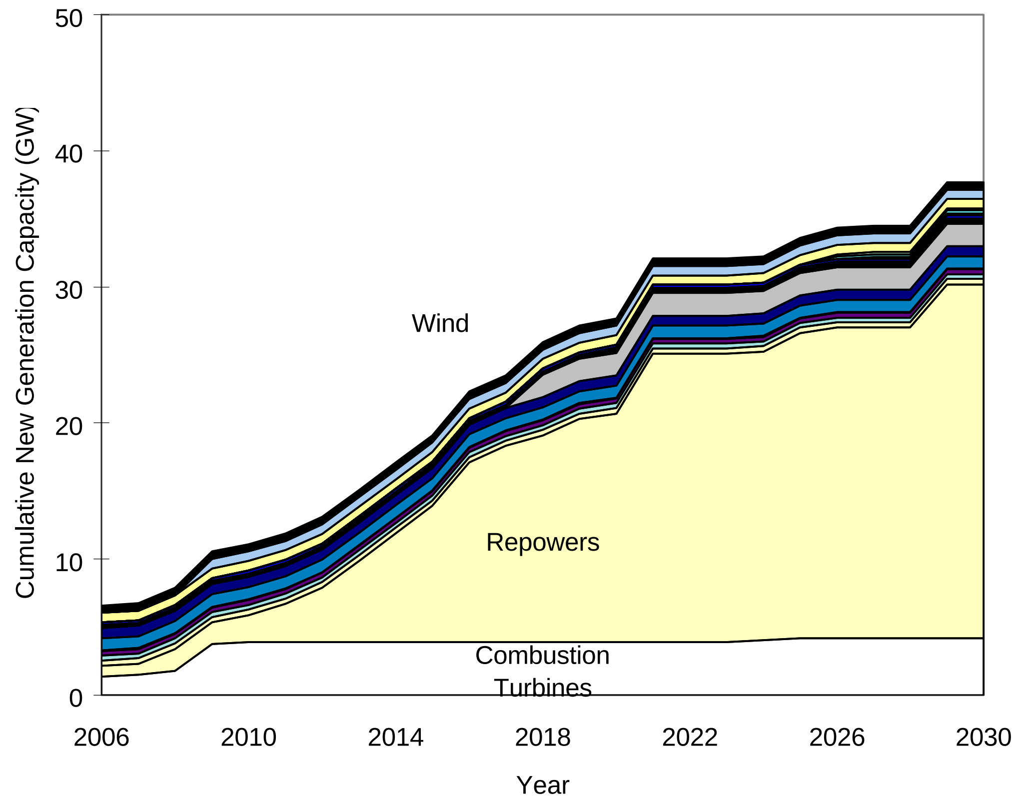
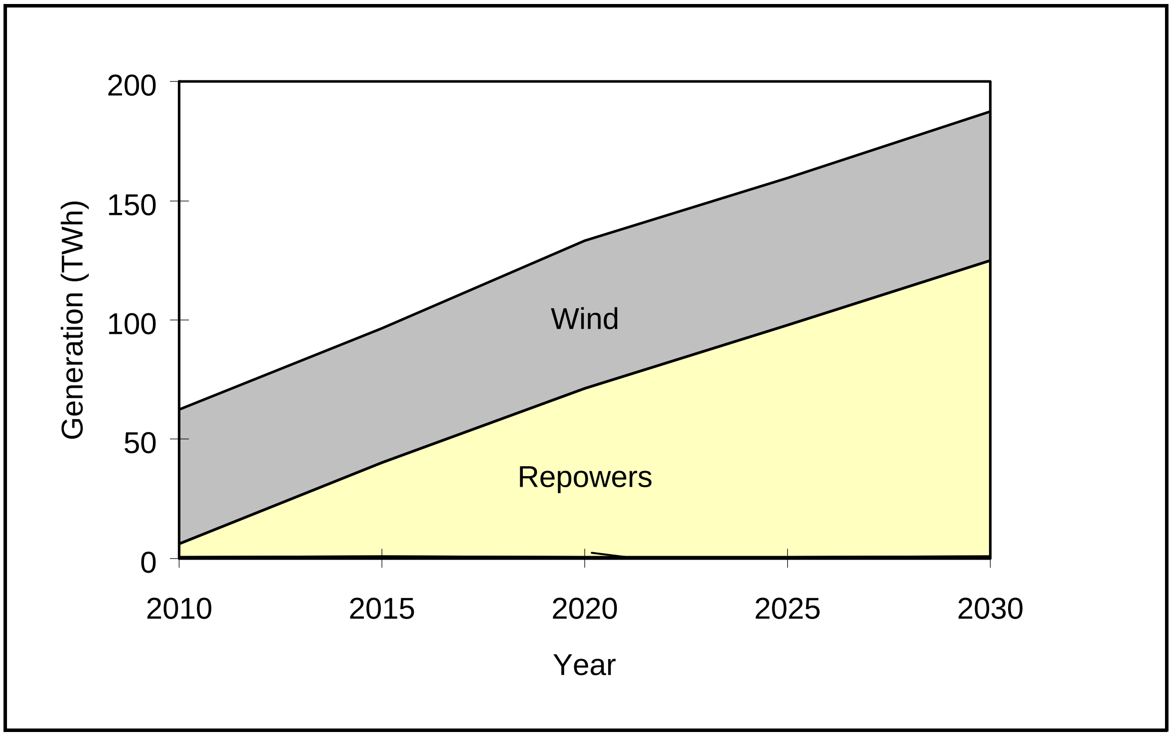


Figure 30. Generation from New Facilities with Actual Wind Resources: High Gas Price Scenario



Comparison of Elfin Model Results with Generic and Actual Resources

Wind patterns are very different between sites, and one has to live with a single pattern in the former representation where only a single generic type is allowed. It is interesting to compare the results for high gas price scenario (Figures 23 and 29). In the generic representation associated with Figure 23, the generic wind pattern is possibly not as favorable, delaying the expansion of wind capacity until after 2018. In fact the wind data which is used for this generic case is from San Gorgonio. It is interesting to note that the development in that region happens also in 2018 for the scenario with detailed wind representation.

Another problem with the former generic representation is that there were no upper capacity limits. With the new, more detailed representation, each site has its capacity limit based on estimated actual physical limits.

Another notable feature of Figures 22, 27, and 29 is the role of repowers. This capacity expansion option, under the assumptions used in this simulation, is highly attractive as the results clearly show. It should be noted, however, that this option shares some key attributes with renewables; notably, development at any site requires unique design features and costs may diverge widely from generic assumptions. Since competition between repowers and renewables may be a feature of future investment patterns, the benefits of the Elfin approach are particularly appealing.

Comparison to Profitability Curve Approach

The differences between the results of the traditional approach and Elfin simulations are: (1) more sites are profitable in the Elfin results, (2) some specific sites are developed earlier or later, and (3), one site that is profitable using the levelized-cost method is not chosen by the Elfin model. Table 7 compares the wind sites shown to be profitable in the previous section to the sites that are developed in the generation expansion plan generated by the Elfin model. By the year 2010, the model chooses not only all the sites that are shown to be profitable using the levelized cost method, but also Sites 10, 12, 21, and 25. By the year 2030, the model chooses most of the sites (all of the sites except Site 34) that are shown profitable using the levelized-cost method. In addition, the Elfin model chooses Sites 8, 11, 17, and 23. Although there are strong similarities, it is clear that simple levelized-cost analysis used in the traditional approach misses some of the sites that are built into the Elfin generation plan.

It can be noted that at one of these sites, Pacheco Pass (Site 35) about 16 MW of wind generation capacity already exists. The results from both methods indicate that this site will not be profitable in the future California electricity market. One possible reason for this is that seasonal diurnal wind patterns are not available for this location and the annual diurnal pattern does not characterize the potential well enough.

Finally, please be reminded that although the rankings in Table 7 are similar, the Elfin plan B is naturally superior in that development at sites can be economically expanded over any of the years of the study period.

Table 7. Profitable Sites Generated by Levelized Cost Method versus the Elfin Model

2010		2030	
Levelized Cost Method	**Elfin**	**Levelized Cost Method**	**Elfin**
6	6	6	6
26	26	24	24
27	27	26	26
30	30	27	27
31	31	2	2
2	2	30	30
29	29	31	31
28	28	4	4
24	24	29	29
4	4	28	28
1	1	7	7
7	7	1	1
3	3	16	16
16	16	3	3
	5	21	21
	10	**34**	15
	12	15	5
	21	5	10
	25	10	25
		25	**8**
			11
			17
			23

7. Emissions

Emission levels generated by Elfin simulations run using a generic wind resource and the more detailed wind-site data developed in this report are shown in Tables 8 and 10, respectively. It is clear that the results for the generic wind-resource case overestimated the emissions due to the fact that no wind resource is developed. Tables 9 and 11 show the change in the emissions relative to the best guess scenario in the generic and detailed wind cases respectively. Results for the generic wind resource case grossly overestimate the emission savings, especially after 2020, because of the huge wind generation capacity expansion which starts in 2018 and makes further big jumps in 2021 and 2025. For the detailed wind case, the savings are not big since the differences between the best-guess and high gas price scenarios are not much different.

Table 8. Best-Guess Scenario with Generic Wind Resources: Emissions (kt)

	2010	2015	2020	2025	2030
oxides of nitrogen	223	226	228	227	224
sulfur oxides	83	85	86	86	85
particulate matter (<10 μm)	10	12	14	15	16
reactive organic gases	34	35	36	37	37
carbon monoxide	69	69	69	69	70
carbon portion of carbon dioxide	26 345	30 883	34 651	37 007	39 684

Table 9. Reduction in Emissions in High Gas Price Scenario with Generic Wind Resources

	2010	2015	2020	2025	2030
oxides of nitrogen	-2%	2%	3%	6%	14%
sulfur oxides	-3%	10%	12%	16%	32%
particulate matter (<10 μm)	2%	0%	12%	26%	41%
reactive organic gases	0%	-1%	2%	6%	13%
carbon monoxide	-1%	0%	2%	4%	11%
carbon portion of carbon dioxide	-1%	0%	13%	28%	44%

Table 10. Best-Guess Scenario with Actual Wind Resources: Emissions (kt)

	2010	2015	2020	2025	2030
oxides of nitrogen	202	212	216	211	214
sulfur oxides	67	71	73	67	71
particulate matter (<10 μm)	8	10	11	12	13
reactive organic gases	32	34	35	35	36
carbon monoxide	66	66	67	67	67
carbon portion of carbon dioxide	19 720	24 040	27 964	29 645	32 671

Table 11. Reduction in Emissions in High Gas Price Scenario with Actual Wind Resources

	2010	2015	2020	2025	2030
oxides of nitrogen	0%	-1%	-1%	-4%	-2%
sulfur oxides	3%	-2%	-3%	-13%	-7%
particulate matter (<10μm)	1%	1%	3%	1%	1%
reactive organic gases	0%	0%	0%	0%	0%
carbon monoxide	0%	-1%	0%	-1%	0%
carbon portion of carbon dioxide	2%	0%	3%	-1%	0%

8. Future Work

Future work will concentrate on three areas: (1) improving the estimation of cost of development and operation at each of the sites, (2) including areas which are either not covered by the CEC studies or which have low average wind speeds but possibly favorable wind profiles, and (3) including out-of-state resources that may compete in the California market.

In this demonstration, costs depended only on the distance to transmission lines and distance to roads and the transmission data used are only approximate. In the future, a more accurate map of transmission lines will be available from the CEC. Since the process for mapping and calculating distances with the FEMA transmission data layer has been set up, improving the accuracy of results by substituting the CEC data for the FEMA data layer is straightforward.

Cost is also a function of the terrain, distance to population centers, land values, and many other factors, many of which are amenable to a GIS approach. More simply, however, one desirable GIS improvement is the inclusion of population density maps for the wind sites which would serve as a proxy for land value. Population data can be obtained from the U.S. Census Bureau, matched with the appropriate polygon data layer (county or tract) and mapped. GIS can also be used to improve cost calculations by incorporating the slopes of the terrain at different sites. This slope affects the cost of construction of both the wind farm and the transmission lines.

The graphic quality of the relief maps can be improved by creating colored three-dimensional grids of the surface. Creating these graphics requires some additional processing that was outside the scope of this project.

The choice of wind sites relies on CEC studies done more than ten years ago. The wind intensity map (Figure 3) indicates favorable areas in the Sierras which are not covered by the CEC studies. The potential for that area could be estimated using newer GIS methods or a tool such as WindMap.[14] Also, the 36 sites selected for this study probably cover most of the wind potential in the studied area but still there may be sites with low annual average wind speeds but very favorable wind patterns or locations which might be profitable. It will be worthwhile to look at all of the sites included in the CEC studies for a second time from this perspective. Finally, there might be remote sites which are far from transmission lines but close to small demand centers.

Parsons and Wan (1995) indicate that the wind potential of areas within 16 km of the transmission lines is about 350 GW in the U.S. The areas covered in this report are only about two percent of this potential. Out-of-state resources sending electricity to California may prove to be profitable and future studies need to investigate such potential.

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[14] WindMap is a proprietary product of Brower & Co.

Other future enhancements will include: (1) introduction of trends in the size of the turbines, (2) modeling power reduction in multiple-row wind sites, (3) examination of the effects of using data from different years for the different sites.

9. Conclusion

In this demonstration analysis, a characterization of the wind potential of California has been developed using archival studies conducted by the CEC and by using GIS. The resource is represented as an Elfin input data set that was subsequently run using the Berkeley Lab's data set for the future competitive electricity market. Preliminary results indicate that about 7.5 GW of the 10-GW potential capacity in the 36 specific sites can be profitably developed by the year 2030 and 62 TWh of electricity can be produced per annum by the year 2030. Furthermore, most of the development happens during the earlier years of the forecast.

Another conclusion is that simple levelized-cost analyses do not sufficiently capture the implications of time-varying prices in a competitive market. The differences between the results of the traditional approach and Elfin simulations are: (1) more sites are profitable in the Elfin results, (2) some specific sites are developed earlier or later, and (3), one site which is shown to be profitable using levelized-cost analysis is not chosen by the Elfin model for development.

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Appendix A: Data on Wind Sites

Table A-1 presents a summary of the characteristics of the sites used in this study (land characteristics, land use, generation capacity, revenues, costs, and wind characteristics). Generation capacity is estimated based on data on the size of the area. Revenues are estimated using the hourly (or every three hours) wind data and the marginal busbar costs for the pool.

Figures A-1 through A-5 depict the diurnal wind patterns for a few sites. For some sites, these patterns are differentiated for only two seasons (Sites 1, 15, 16, 24, 26, 27, 28, 29, 30, 31). For the coastal mountain sites (Sites 32, 33, 34, 35, and 36) the diurnal patterns are not differentiated seasonally.

Table A-1. Wind Site Characteristics

Site	1 Bear River Ridge	2 Solano Hills (good)	3 Solano Hills (marginal)	4 Altamont Pass (good)	5 Altamont Pass (marginal)	6 San Gorgonio (best)
Land Characteristics	97 km (60 mi) of ridge line	31 km^2 7700 acres	26 km^2 6400 acres	52 km^2 13,000 acres	68 km^2 17,000 acres	80 km^2 20,000 acres
Land Use		Cattle Grazing	Cattle Grazing	Cattle Grazing	Cattle Grazing	Rural Residential
Estimated Generation Capacity						
Potential Capacity (MW) {CEC}	425	500 (all Solano)	500 (all Solano)	1000 (all Altamont)	1000 (all Altamont)	3300 (all San Gorgonio)
Potential Capacity (MW) {LBNL}	**399**	**397**	**330**	**670**	**876**	**309**
Potential Electricity Output (TWh/a) {CEC}		1.2 (all Solano)	1.2 (all Solano)	2.4 (all Altamont)	2.4 (all Altamont)	7 (all San Gorgonio)
Estimated Revenues						
Revenue per Wind Generator ($/a)	68093	106148	59285	71938	40179	178635
Revenue for the Site (M$/a)	**54.339**	**84.186**	**39.081**	**96.326**	**70.353**	**110.396**
Estimated Costs						
Distance to Transmission Lines (km)	35.3	0.7	0.4	0.7	1.3	1.3
Cost to Connect to the Grid ($)	4889000	391000	352000	391000	469000	469000
Substation ($)	3000000	3000000	3000000	3000000	3000000	3000000
Cost of Lines Within the Farm ($)	4800000	4584195	3810240	7739550	10120950	3572100
Distance to Roads (km)	4.4	2.9	2.6	2.3	0.3	3.7
Cost to Connect to the Existing Roads ($)	96800	63800	57200	50600	6600	81400
Land Costs ($)[15]	13200	8700	7800	6900	900	11100
Cost of Turbines (million $)	399	396.55	329.6	669.5	875.5	309
Total Capital Outlay (M$)	**411.799**	**404.598**	**336.827**	**680.688**	**889.097**	**316.134**
Capital Outlay/kW	1032	1020	1022	1017	1016	1023
Maintenance (M$/a) (est LF 0.3)	**12.583**	**12.506**	**10.394**	**21.113**	**27.610**	**9.745**
Rent for Land (M$/a)	**0.3192**	**0.31724**	**0.26368**	**0.5356**	**0.7004**	**0.618**
Wind Characteristics						
Average Annual Wind Speed (m/s)	**7.3**	**7.5**	**6.2**	**7.5**	**6.2**	**9.9**

15 1 km requires 0.006 km^2 (1.5 acre); 0.004 km^2 (1 acre) costs $2 000

Table A-1. Wind Site Characteristics *(continued)*

Site	7 San Gorgonio (good) Whitewater	8 San Gorgonio (marginal) Cabazon	9 Tehachapi Pass (good) Cameron and Oak Ridges	10 Tehachapi Pass (good) Pajuela Peak	11 Tehachapi Pass (marginal) Downslope (CPC-1)	12 Tehachapi Mountains La Liebre Ridge (half good)
Land Characteristics	80 km^2 (best+good) 20 000 acres (best+good) 14 000 acres (est.)	128 km^2 32 000 acres	23 km of ridge 14 miles of ridge	5 km ridge 3 miles ridge	52 km^2 20 sq.miles	23 km ridgeline 14 miles ridgeline
Land Use	Rural Residential	Rural Residential				
Estimated Generation Capacity						
Potential Capacity (MW) {CEC}	3 300 (all San Gorgonio)	3 300 (All San Gorgonio)	575 (all T. Pass)		575 (all T. Pass)	280
Potential Capacity (MW) {LBNL}	721	1 648	93	20	674	93
Potential Electricity Output (TWh/a) {CEC}	7 (all San Gorgonio)	7 (all San Gorgonio)				
Estimated Revenues						
Revenue per Wind Generator ($/a)	61 257	28 166	54 168	54 168	24 898	32 678
Revenue for the Site (M$/a)	88.332	92.836	10.086	2.161	33.568	6.085
Estimated Costs						
Distance to Transmission Lines (km)	3.3	0.7	22.2	40.4	13.6	3.2
Cost to Connect to the Grid ($)	729 000	391 000	3 186 000	5 552 000	2 068 000	716 000
Substation ($)	3 000 000	3 000 000	3 000 000	3 000 000	3 000 000	3 000 000
Cost of Lines Within the Farm ($)	8 334 900	19 051 200	1 120 000	240 000	7 770 000	1 120 000
Distance to Roads (km)	*0.7*	*1.3*	*1.6*	*7.1*	*12.7*	*9.6*
Cost to Connect to Existing Roads ($)	15400	28600	35200	156200	279400	211200
Cost of Turbines (million $)	721	1648	93.1	19.95	674.1	93.1
Total Capital Outlay (M$)	733.081	1670.475	100.446	28.920	687.256	98.176
Capital Outlay/kW	1017	1014	1079	1450	1020	1055
Maintenance (M$/a) (est LF 0.3)	22.737	51.971	2.936	0.629	21.258	2.936
Rent for Land (M$/a)	*1.442*	*3.296*	*0.07448*	*0.01596*	*0.53928*	*0.07448*
Wind Characteristics						
Average Annual Wind Speed (m/s)	7.4	5.9	6.9	6.9	5.5	6.1

Table A-1. Wind Site Characteristics *(continued)*

Site	13 **Barstow (good)**	14 **Barstow (marginal)** four locations	15 **Mountain Pass (good)**	16 **Mountain Pass (good)** Clark Mountains	17 **Gorman** Sandberg	18 **Sierra Pelona**
Land Characteristics	3 km^2 1 sq. mile	23 km^2 9 sq. miles	2 km 1 mile ridge	3 km^2 1 sq. mile	13 km^2 5 sq. miles	29 km ridge 18 miles ridge
Land Use						
Estimated Generation Capacity						
Potential Capacity (MW) {CEC}	75 (all Barstow)	75 (all Barstow)	25 (all pass)	25 (all pass)		
Potential Capacity (MW) {LBNL}	34	303	7	34	169	120
Potential Electricity Output (TWh/a) {CEC}						
Estimated Revenues						
Revenue per Wind Generator ($/a)	0	0	59 196	59 196	26 433	17 374
Revenue for the Site (M$/a)	-	-	0.787	3.990	8.909	4.159
Estimated Costs						
Distance to Transmission Lines (km)	0.8	0.3	1.3	0.4	1.1	6.2
Cost to Connect to the Grid ($)	404 000	339 000	469 000	352 000	443 000	1 106 000
Substation ($)	3 000 000	3 000 000	3 000 000	3 000 000	3 000 000	3 000 000
Cost of Lines Within the Farm ($)	388 500	3 496 500	80 000	388 500	1 942 500	1 440 000
Distance to Roads (km)	0.4	2.1	3	3.9	0.3	4.9
Cost to Connect to the Existing Roads ($)	8 800	46 200	66 000	85 800	6 600	107 800
Land Costs ($)	1 200	6 300	9 000	11 700	900	14 700
Cost of Turbines (million $)	33.705	303.345	6.65	33.705	168.525	119.7
Total Capital Outlay (M$)	37.508	310.233	10.274	37.543	173.918	125.369
Capital Outlay/kW	1113	1 023	1 545	1 114	1 032	1 047
Maintenance (M$/a) (est LF 0.3)	1.063	9.566	0.210	1.063	5.315	3.775
Rent for Land (M$/a)	0.026964	0.242676	0.00532	0.026964	0.13482	0.09576
Wind Characteristics						
Average Annual Wind Speed (m/s)		2.7	7.6	7.6	5.8	5.0

Table A-1. Wind Site Characteristics *(continued)*

Site	19 **Soledad Canyon**	20 **Portal Ridge** Assumption	21 **Fairmont Reservoir**	22 **Santa Catalina** Ben Weston Ridge	23 **Cajon Pass**	24 **Cajon Mountain**
Land Characteristics	13 km^2	32 km ridge	52 km^2 (estimate)	8 km^2	52 km^2	8 km of ridge
	5 sq.miles	20 miles ridge	20 sq. miles (estimate)	3 sq. miles	20 sq. miles	5 miles of ridge
Land Use		Ranchland			Private Parcels	
Estimated Generation Capacity						
Potential Capacity (MW) {CEC}						
Potential Capacity (MW) {LBNL}	**169**	**133**	**674**	**101**	**674**	**33**
Potential Electricity Output (TWh/a) {CEC}						
Estimated Revenues						
Revenue per Wind Generator ($/a)	17 374	17 374	44 700	0	23 782	85 213
Revenue for the Site (M$/a)	**5.856**	**4.621**	**60.265**	**-**	**32.062**	**5.667**
Estimated Costs						
Distance to Transmission Lines (km)	0.6	1.8	1.1		4.7	1.2
Cost to Connect to the Grid ($)	378 000	534 000	443 000		911 000	456 000
Substation ($)	3 000 000	3 000 000	3 000 000	3 000 000	3 000 000	3 000 000
Cost of Lines within the Farm ($)	1 942 500	1 600 000	7 770 000		7 770 000	400 000
Distance to Roads (km)	9.2	0.4	5.3		3.2	0.4
Cost to Connect to the Existing Roads ($)	202 400	8 800	116 600		70 400	8 800
Land Costs ($)	27 600	1 200	15 900	0	9 600	1 200
Cost of Turbines (million $)	168.525	133	674.1	101.115	674.1	33.25
Total Capital Outlay (M$)	**174.076**	**138.144**	**685.446**		**685.861**	**37.116**
Capital Outlay/kW	1 033	1 039	1 017	#VALUE!	1 017	1 116
Maintenance (M$/a) (est LF 0.3)	**5.315**	**4.194**	**21.258**	**3.189**	**21.258**	**1.049**
Rent for Land (M$/a)	**0.13482**	**0.1064**	**0.53928**	**0.080892**	**0.53928**	**0.0266**
Wind Characteristics						
Average Annual Wind Speed (m/s)	**5.0**	**5.0**			**5.3**	

Table A-1. Wind Site Characteristics *(continued)*

Site	25 **Strawberry Peak**	26 **Mt. Laguna**	27 **Julian** Vulcan Mtn	28 **In-Ko_Pah** Boulder Park	**29** Sugarloaf Mtn.	30 **Table Mountain**
Land Characteristics	16 km ridge (est.)	24 km of ridge	16 km ridge	6 km ridge (estimate)		8 km ridge (estimate)
	10 miles ridge (est.)	15 miles of ridge	10 miles ridge	4 miles ridge (estimate)		5 miles ridge (estimate)
Land Use						
Estimated Generation Capacity						
Potential Capacity (MW) {CEC}		220		55		65
Potential Capacity (MW) {LBNL}	67	100	67	12	12	32
Potential Electricity Output (TWh/a) {CEC}						
Estimated Revenues						
Revenue per Wind Generator ($/a)	39 683	183 795	183 795	183 795	183 795	183 795
Revenue for the Site (M$/a)	5.278	36.667	24.445	4.583	4.583	11.667
Estimated Costs						
Distance to Transmission Lines (km)	0.2	29.6	26.3	49.6	40.3	49.6
Cost to Connect to the Grid ($)	326 000	4 148 000	3 719 000	6 748 000	5 539 000	6 748 000
Substation ($)	3 000 000	3 000 000	3 000 000	3 000 000	3 000 000	3 000 000
Cost of Lines within the Farm ($)	800000	1200000	800000	160000	160 000	400 000
Distance to Roads (km)	1.2	0.4	2.2	1.6	0.9	3.7
Cost to Connect to the Existing Roads ($)	26 400	8800	48400	35200	19800	81 400
Land Costs ($)	3600	1200	6600	4800	2700	11 100
Cost of Turbines (million $)	66.5	99.75	66.5	12.47	12.47	**31.74**
Total Capital Outlay (M$)	**70.656**	**108.108**	**74.074**	**22.417**	**21.190**	**41.979**
Capital Outlay/kW	1062	1084	1114	1798	1699	1323
Maintenance (M$/a) (est LF 0.3)	**2.097**	**3.146**	**2.097**	**0.393**	**0.393**	**1.001**
Rent for Land (M$/a)	**0.0532**	**0.0798**	**0.0532**	**0.0100**	**0.0100**	**0.0254**
Wind Characteristics						
Average Annual Wind Speed (m/s)	6.6	7.9	8.6	9.0	6.4	8.8

Table A-1. Wind Site Characteristics *(continued)*

Site	31 **Jacumba Mountains**	32 **Walker Ridge**	33 **Berryessa Peak**	34 **Potrero Hills**	35 **Pacheco Pass**	36 **Cottonwood Pass**
Land Characteristics	5 km of ridge	8 km of ridge	16 km of ridge	31 km^2	13 km^2 (estimate)	13 km^2 (estimate)
	3 miles of ridge	5 miles of ridge	10 miles of ridge	12 sq. miles	5 sq. miles (estimate)	5 sq. miles (estimate)
Land Use						
Estimated Generation Capacity						
Potential Capacity (MW) {CEC}	45					
Potential Capacity (MW) {LBNL}	20	33	67	404	169	169
Potential Electricity Output (TWh/a) {CEC}						
Estimated Revenues						
Revenue per Wind Generator ($/a)	**183 795**	**32 360**	**16 756**	**48 458**	**17 550**	**25 945**
Revenue for the Site (M$/a)	7.333	2.152	2.228	39.198	5.915	8.745
Estimated Costs						
Distance to Transmission Lines (km)	**49.6**	**2.8**	**5.7**	**4.4**	**7.4**	**11**
Cost to Connect to the Grid ($)	**6 748 000**	**664 000**	**1 041 000**	**872 000**	**1 262 000**	**1 730 000**
Substation ($)	**3 000 000**	**3 000 000**	**3 000 000**	**3 000 000**	**3 000 000**	**3 000 000**
Cost of Lines within the Farm ($)	**240 000**	**400 000**	**800 000**	**4 662 000**	**1 942 500**	**1 942 500**
Distance to Roads (km)	**5.1**	**4.3**	**5.5**	**2.4**	**0.3**	**0.1**
Cost to Connect to the Existing Roads ($)	**112 200**	**94 600**	**121 000**	**52 800**	**6 600**	**2 200**
Land Costs ($)	15 300	12900	16500	7200	900	300
Cost of Turbines (million $)	**19.95**	**33.25**	**66.5**	**404.46**	**168.525**	**168.525**
Total Capital Outlay (M$)	**30.066**	**37.422**	**71.479**	**413.054**	**174.737**	**175.200**
Capital Outlay/kW	**1 507**	**1 125**	**1 075**	**1 021**	**1 037**	**1 040**
Maintenance (M$/a) (est LF 0.3)	**0.629**	**1.049**	**2.097**	**12.755**	**5.315**	**5.315**
Rent for Land (M$/a)	**0.01596**	**0.0266**	**0.0532**	**0.323568**	**0.13482**	**0.13482**
Wind Characteristics						
Average Annual Wind Speed (m/s)	**8.8**	**6.7**	**5.2**	**7.2**	**5.2**	**5.5**

Figure A-1. Solano Hills (Site 2) Wind Pattern

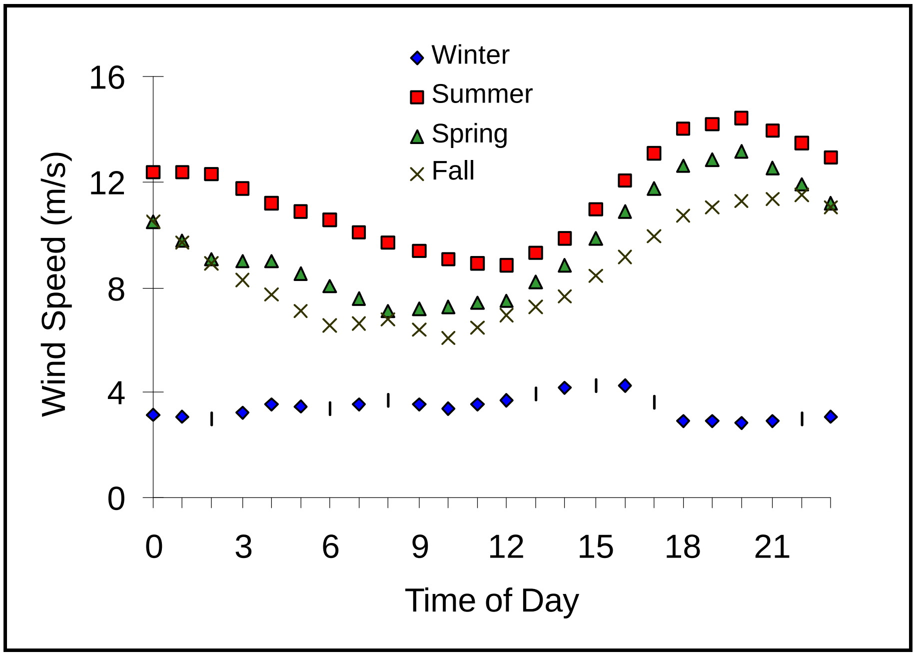


Figure A-2. San Gorgonio (Site 6) Wind Pattern

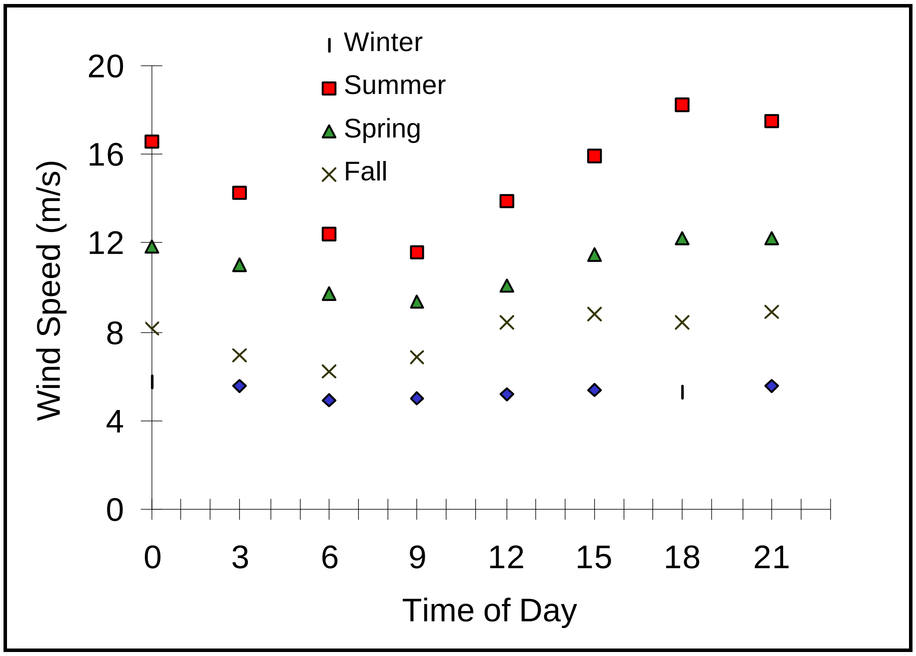


Figure A-3. In-Ko-Pah (Site 28) Wind Pattern

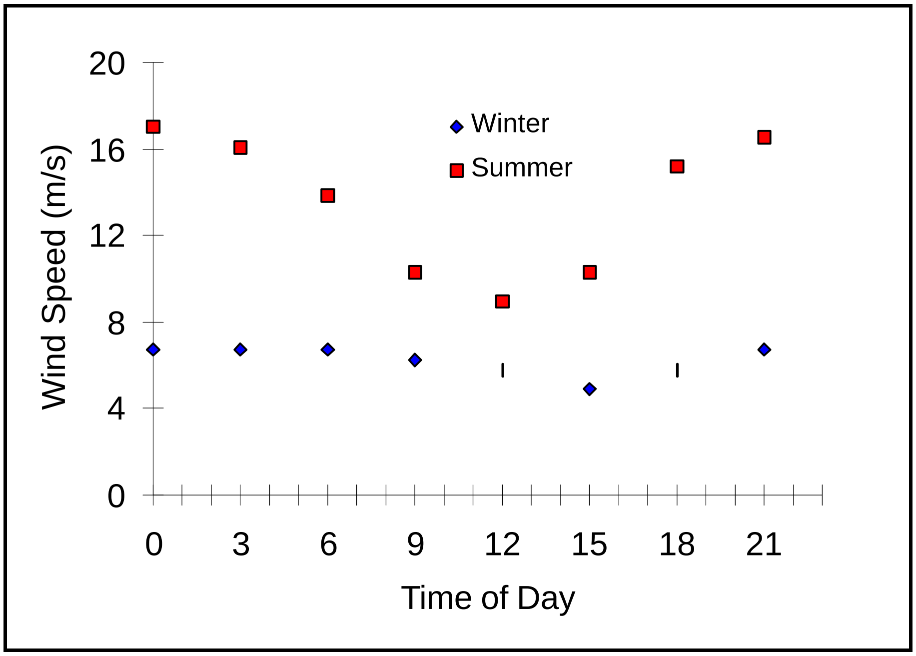


Figure A-4. Altamont Pass (Site 4) Wind Pattern

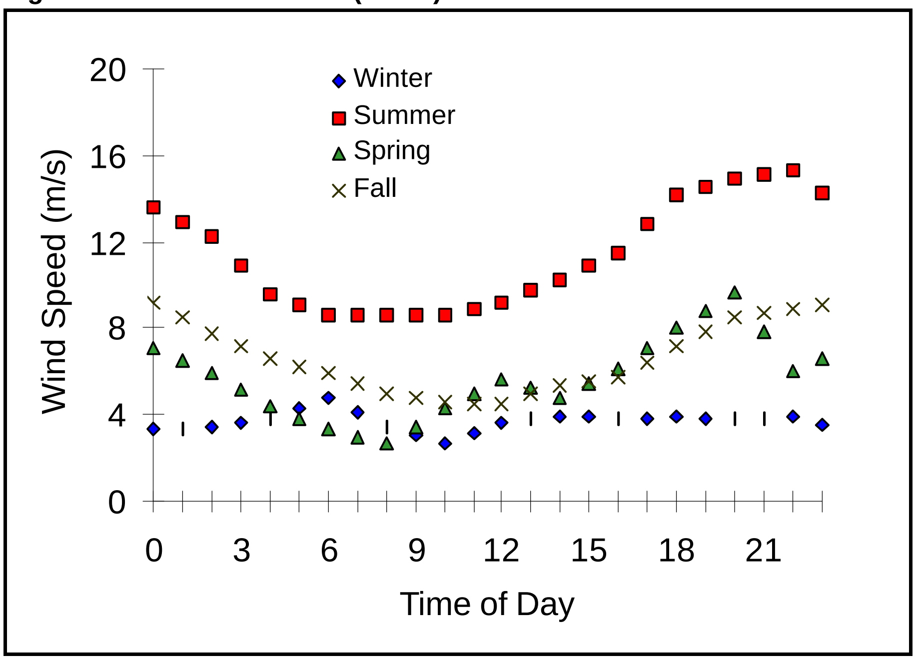
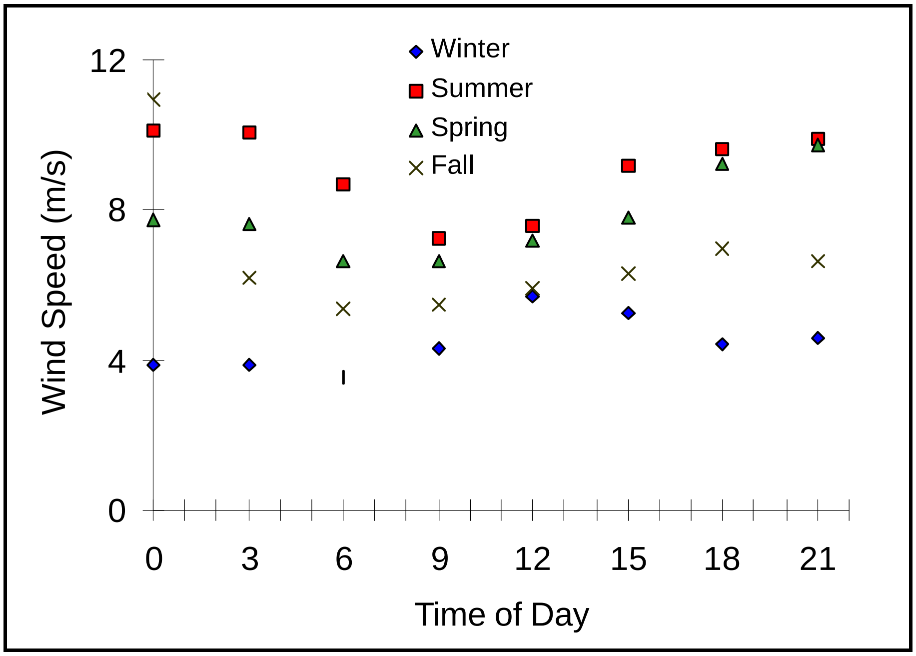


Figure A-5. Tehachapi Pass (Site 9) Wind Pattern



Appendix B: Sample Wind Input to the Elfin Model

36 actual sites from the CEC studies.

Site 1

```
wn01cp 1
        nc=50  #dc=50
        22  33.30   33.30    78.94   78.94   78.94   78.94
             78.94   78.94    33.30   33.30   33.30    33.30
wn01mu 1
        17  y1991   0
wn01fc 1
        2   0
wn01mr 1
        2   0.025
wn01fr 1
        2   0.000
wn01vi 1 changed to 1995$; assuming .0075 real escalation
        $/kwh   2   0.00
wn01vx 1
        vx=srch
wn01kp 1 base case capital costs
        pl=30   es=0.0   y$=1995 lf=0.09
        $/kw  1   1032 Y1995 0.0 Y1996 -0.0115  Y2031 0.0
wn01mx 1 this scenario is to exclude the resource in the default case
        17  y1995   0
wn01mx 2 this scenario to preclude this option
        17  y1995   0
wn01mx 51
        17  y1995   0
           y1996   8
wn01fx 1 changed to 1995$
        y$=1995   es=genf
        $/kw  2   26
wn01sh 1 Subperiod shaping
        29 y199101 mon          12am    0.579     3am  0.523     6am  0.377
                                9am    0.523    12pm  0.579     3pm  0.770
                                6pm    1.000     9pm  0.842
          y199103 mon                    12am    0.579     3am  0.388     6am  0.388
                                9am    0.388    12pm  0.388     3pm  0.719
```

	6pm	1.000	9pm	0.824			
y199106 mon	12am	0.579	3am	0.388	6am	0.388	
	9am	0.388	12pm	0.388	3pm	0.719	
	6pm	1.000	9pm	0.824			
y199109 mon	12am	0.579	3am	0.523	6am	0.377	
	9am	0.523	12pm	0.579	3pm	0.770	
	6pm	1.000	9pm	0.842			
y199112 mon	12am	0.579	3am	0.523	6am	0.377	
	9am	0.523	12pm	0.579	3pm	0.770	
	6pm	1.000	9pm	0.842			