APPENDIX D:
Wind-Diesel System Operational Guidelines

This appendix contains the wind-diesel system operational guidelines that lead to the overall operational scenario. This scenario was developed by NREL and its sub-contractors for the SERDP-funded San Clemente Island wind turbine installation.

This appendix conveys information on the amount of wind turbine electrical energy that can be utilized with the SCI diesel system and on the appropriate use of external loads to manage excess wind energy. Fuel savings are still achievable with low demand when the wind-diesel system includes a 225 kW load bank.

	WIND SPEED (mph)											
DEMAND	10				15				20			
LOAD (kW)	#WG	WG (kW)	DG (kW)	LB (kW)	#WG	WG (kW)	DG (kW)	LB (kW)	#WG	WG (kW)	DG (kW)	LB (kW)
400	1	19.5	380.5	0.0	1	57.1	342.9	0.0	1	118.7	281.3	0.0
	2	39.0	361.0	0.0	2	114.2	285.8	0.0	2	237.4	162.6	0.0
	3	58.5	341.5	0.0	3	171.3	228.7	0.0	3	356.1	118.9	75.0
	4	78.0	322.0	0.0	4	228.4	171.6	0.0	4	474.8	150.2	225.0
500	1	19.5	480.5	0.0	1	57.1	442.9	0.0	1	118.7	381.3	0.0
	2	39.0	461.0	0.0	2	114.2	385.8	0.0	2	237.4	262.6	0.0
	3	58.5	441.5	0.0	3	171.3	328.7	0.0	3	356.1	143.9	0.0
	4	78.0	422.0	0.0	4	228.4	271.6	0.0	4	474.8	100.2	75.0
600	1	19.5	580.5	0.0	1	57.1	542.9	0.0	1	118.7	481.3	0.0
	2	39.0	561.0	0.0	2	114.2	485.8	0.0	2	237.4	362.6	0.0
	3	58.5	541.5	0.0	3	171.3	428.7	0.0	3	356.1	243.9	0.0
	4	78.0	522.0	0.0	4	228.4	371.6	0.0	4	474.8	125.2	0.0
700	1	19.5	680.5	0.0	1	57.1	642.9	0.0	1	118.7	581.3	0.0
	2	39.0	661.0	0.0	2	114.2	585.8	0.0	2	237.4	462.6	0.0
	3	58.5	641.5	0.0	3	171.3	528.7	0.0	3	356.1	343.9	0.0
	4	78.0	622.0	0.0	4	228.4	471.6	0.0	4	474.8	225.2	0.0
800	1	19.5	780.5	0.0	1	57.1	742.9	0.0	1	118.7	681.3	0.0
	2	39.0	761.0	0.0	2	114.2	685.8	0.0	2	237.4	562.6	0.0
	3	58.5	741.5	0.0	3	171.3	628.7	0.0	3	356.1	443.9	0.0
	4	78.0	722.0	0.0	4	228.4	571.6	0.0	4	474.8	325.2	0.0
900	1	19.5	880.5	0.0	1	57.1	842.9	0.0	1	118.7	781.3	0.0
	2	39.0	861.0	0.0	2	114.2	785.8	0.0	2	237.4	662.6	0.0
	3	58.5	841.5	0.0	3	171.3	728.7	0.0	3	356.1	543.9	0.0
	4	78.0	822.0	0.0	4	228.4	671.6	0.0	4	474.8	425.2	0.0
1000	1	19.5	980.5	0.0	1	57.1	942.9	0.0	1	118.7	881.3	0.0
	2	39.0	961.0	0.0	2	114.2	885.8	0.0	2	237.4	762.6	0.0
	3	58.5	941.5	0.0	3	171.3	828.7	0.0	3	356.1	643.9	0.0
	4	78.0	922.0	0.0	4	228.4	771.6	0.0	4	474.8	525.2	0.0
1100	1	19.5	1,080.5	0.0	1	57.1	1,042.9	0.0	1	118.7	981.3	0.0
	2	39.0	1,061.0	0.0	2	114.2	985.8	0.0	2	237.4	862.6	0.0
	3	58.5	1,041.5	0.0	3	171.3	928.7	0.0	3	356.1	743.9	0.0
	4	78.0	1,022.0	0.0	4	228.4	871.6	0.0	4	474.8	625.2	0.0
1200	1	19.5	1,180.5	0.0	1	57.1	1,142.9	0.0	1	118.7	1,081.3	0.0
	2	39.0	1,161.0	0.0	2	114.2	1,085.8	0.0	2	237.4	962.6	0.0
	3	58.5	1,141.5	0.0	3	171.3	1,028.7	0.0	3	356.1	843.9	0.0
	4	78.0	1,122.0	0.0	4	228.4	971.6	0.0	4	474.8	725.2	0.0
1300	1	19.5	1,280.5	0.0	1	57.1	1,242.9	0.0	1	118.7	1,181.3	0.0
	2	39.0	1,261.0	0.0	2	114.2	1,185.8	0.0	2	237.4	1,062.6	0.0
	3	58.5	1,241.5	0.0	3	171.3	1,128.7	0.0	3	356.1	943.9	0.0
	4	78.0	1,222.0	0.0	4	228.4	1,071.6	0.0	4	474.8	825.2	0.0
1400	1	19.5	1,380.5	0.0	1	57.1	1,342.9	0.0	1	118.7	1,281.3	0.0
	2	39.0	1,361.0	0.0	2	114.2	1,285.8	0.0	2	237.4	1,162.6	0.0
	3	58.5	1,341.5	0.0	3	171.3	1,228.7	0.0	3	356.1	1,043.9	0.0
	4	78.0	1,322.0	0.0	4	228.4	1,171.6	0.0	4	474.8	925.2	0.0
1500	1	19.5	1,480.5	0.0	1	57.1	1,442.9	0.0	1	118.7	1,381.3	0.0
	2	39.0	1,461.0	0.0	2	114.2	1,385.8	0.0	2	237.4	1,262.6	0.0
	3	58.5	1,441.5	0.0	3	171.3	1,328.7	0.0	3	356.1	1,143.9	0.0
	4	78.0	1,422.0	0.0	4	228.4	1,271.6	0.0	4	474.8	1,025.2	0.0

KEY

#WG : NUMBER OF WIND GENERATORS
WG : WIND GENERATOR LOAD PRODUCTION (kW)
DG : DIESEL GENERATOR LOAD PRODUCTION (kW)
LB : LOAD BANK LOAD DISSIPATION (kW)

	WIND SPEED (mph)											
DEMAND	25				30				35			
LOAD (kW)	#WG	WG (kW)	DG (kW)	LB (kW)	#WG	WG (kW)	DG (kW)	LB (kW)	#WG	WG (kW)	DG (kW)	LB (kW)
400	1	171.4	228.6	0.0	1	206.0	194.0	0.0	1	227.0	173.0	0.0
	2	342.8	132.2	75.0	2	412.0	138.0	150.0	2	454.0	171.0	225.0
	3	514.2	110.8	225.0	3	OFF			3	OFF		
	4	OFF			4	OFF			4	OFF		
500	1	171.4	328.6	0.0	1	206.0	294.0	0.0	1	227.0	273.0	0.0
	2	342.8	157.2	0.0	2	412.0	163.0	75.0	2	454.0	121.0	75.0
	3	514.2	135.8	150.0	3	618.0	107.0	225.0	3	OFF		
	4	OFF			4	OFF			4	OFF		
600	1	171.4	428.6	0.0	1	206.0	394.0	0.0	1	227.0	373.0	0.0
	2	342.8	257.2	0.0	2	412.0	188.0	0.0	2	454.0	146.0	0.0
	3	514.2	160.8	75.0	3	618.0	132.0	150.0	3	681.0	144.0	225.0
	4	685.6	139.4	225.0	4	OFF			4	OFF		
700	1	171.4	528.6	0.0	1	206.0	494.0	0.0	1	227.0	473.0	0.0
	2	342.8	357.2	0.0	2	412.0	288.0	0.0	2	454.0	246.0	0.0
	3	514.2	185.8	0.0	3	618.0	157.0	75.0	3	681.0	169.0	150.0
	4	685.6	164.4	150.0	4	824.0	101.0	225.0	4	OFF		
800	1	171.4	628.6	0.0	1	206.0	594.0	0.0	1	227.0	573.0	0.0
	2	342.8	457.2	0.0	2	412.0	388.0	0.0	2	454.0	346.0	0.0
	3	514.2	285.8	0.0	3	618.0	182.0	0.0	3	681.0	119.0	0.0
	4	685.6	114.4	0.0	4	824.0	126.0	150.0	4	908.0	117.0	225.0
900	1	171.4	728.6	0.0	1	206.0	694.0	0.0	1	227.0	673.0	0.0
	2	342.8	557.2	0.0	2	412.0	488.0	0.0	2	454.0	446.0	0.0
	3	514.2	385.8	0.0	3	618.0	282.0	0.0	3	681.0	219.0	0.0
	4	685.6	214.4	0.0	4	824.0	151.0	75.0	4	908.0	142.0	150.0
1000	1	171.4	828.6	0.0	1	206.0	794.0	0.0	1	227.0	773.0	0.0
	2	342.8	657.2	0.0	2	412.0	588.0	0.0	2	454.0	546.0	0.0
	3	514.2	485.8	0.0	3	618.0	382.0	0.0	3	681.0	319.0	0.0
	4	685.6	314.4	0.0	4	824.0	176.0	0.0	4	908.0	167.0	75.0
1100	1	171.4	928.6	0.0	1	206.0	894.0	0.0	1	227.0	873.0	0.0
	2	342.8	757.2	0.0	2	412.0	688.0	0.0	2	454.0	646.0	0.0
	3	514.2	585.8	0.0	3	618.0	482.0	0.0	3	681.0	419.0	0.0
	4	685.6	414.4	0.0	4	824.0	276.0	0.0	4	908.0	192.0	0.0
1200	1	171.4	1,028.6	0.0	1	206.0	994.0	0.0	1	227.0	973.0	0.0
	2	342.8	857.2	0.0	2	412.0	788.0	0.0	2	454.0	746.0	0.0
	3	514.2	685.8	0.0	3	618.0	582.0	0.0	3	681.0	519.0	0.0
	4	685.6	514.4	0.0	4	824.0	376.0	0.0	4	908.0	292.0	0.0
1300	1	171.4	1,128.6	0.0	1	206.0	1,094.0	0.0	1	227.0	1,073.0	0.0
	2	342.8	957.2	0.0	2	412.0	888.0	0.0	2	454.0	846.0	0.0
	3	514.2	785.8	0.0	3	618.0	682.0	0.0	3	681.0	619.0	0.0
	4	685.6	614.4	0.0	4	824.0	476.0	0.0	4	908.0	392.0	0.0
1400	1	171.4	1,228.6	0.0	1	206.0	1,194.0	0.0	1	227.0	1,173.0	0.0
	2	342.8	1,057.2	0.0	2	412.0	988.0	0.0	2	454.0	946.0	0.0
	3	514.2	885.8	0.0	3	618.0	782.0	0.0	3	681.0	719.0	0.0
	4	685.6	714.4	0.0	4	824.0	576.0	0.0	4	908.0	492.0	0.0
1500	1	171.4	1,328.6	0.0	1	206.0	1,294.0	0.0	1	227.0	1,273.0	0.0
	2	342.8	1,157.2	0.0	2	412.0	1,088.0	0.0	2	454.0	1,046.0	0.0
	3	514.2	985.8	0.0	3	618.0	882.0	0.0	3	681.0	819.0	0.0
	4	685.6	814.4	0.0	4	824.0	676.0	0.0	4	908.0	592.0	0.0

KEY

#WG : NUMBER OF WIND GENERATORS
WG : WIND GENERATOR LOAD PRODUCTION (kW)
DG : DIESEL GENERATOR LOAD PRODUCTION (kW)
LB : LOAD BANK LOAD DISSIPATION (kW)

	WIND SPEED (mph)			
DEMAND	40			
LOAD (kW)	#WG	WG (kW)	DG (kW)	LB (kW)
400	1	230.0	170.0	0.0
	2	460.0	165.0	225.0
	3	OFF		
	4	OFF		
500	1	230.0	270.0	0.0
	2	460.0	115.0	75.0
	3	OFF		
	4	OFF		
600	1	230.0	370.0	0.0
	2	460.0	140.0	0.0
	3	690.0	135.0	225.0
	4	OFF		
700	1	230.0	470.0	0.0
	2	460.0	240.0	0.0
	3	690.0	160.0	150.0
	4	OFF		
800	1	230.0	570.0	0.0
	2	460.0	340.0	0.0
	3	690.0	110.0	0.0
	4	920.0	105.0	225.0
900	1	230.0	670.0	0.0
	2	460.0	440.0	0.0
	3	690.0	210.0	0.0
	4	920.0	130.0	150.0
1000	1	230.0	770.0	0.0
	2	460.0	540.0	0.0
	3	690.0	310.0	0.0
	4	920.0	155.0	75.0
1100	1	230.0	870.0	0.0
	2	460.0	640.0	0.0
	3	690.0	410.0	0.0
	4	920.0	180.0	0.0
1200	1	230.0	970.0	0.0
	2	460.0	740.0	0.0
	3	690.0	510.0	0.0
	4	920.0	280.0	0.0
1300	1	230.0	1,070.0	0.0
	2	460.0	840.0	0.0
	3	690.0	610.0	0.0
	4	920.0	380.0	0.0
1400	1	230.0	1,170.0	0.0
	2	460.0	940.0	0.0
	3	690.0	710.0	0.0
	4	920.0	480.0	0.0
1500	1	230.0	1,270.0	0.0
	2	460.0	1,040.0	0.0
	3	690.0	810.0	0.0
	4	920.0	580.0	0.0

KEY

#WG : NUMBER OF WIND GENERATORS
WG : WIND GENERATOR LOAD PRODUCTION (kW)
DG : DIESEL GENERATOR LOAD PRODUCTION (kW)
LB : LOAD BANK LOAD DISSIPATION (kW)

INPUT

WIND SPEED (mph)	GEN LOAD (kW)	DG LOAD MIN (kW)	DG INC (kW)
10	19.5	100.0	75.0
15	57.1		
20	118.7		
25	171.4		
30	206.0		
35	227.0		
40	230.0		

105.0

NREL: SAN CLEMENTE ISLAND

FUEL CONSUMPTION ESTIMATE

	WIND SPEED (10 mph)					
DEMAND LOAD (kW)	#WG	WG (kW)	DG (kW)	FUEL DEMAND (gal/hr)	FUEL USED (gal/hr)	FUEL SAVED (gal/hr)
800	1	19.5	780.5	51.6	50.3	1.3
	2	39.0	761.0	51.6	48.8	2.8
	3	58.5	741.5	51.6	47.7	3.9
	4	78.0	722.0	51.6	46.7	4.9

	WIND SPEED (15 mph)					
DEMAND LOAD (kW)	#WG	WG (kW)	DG (kW)	FUEL DEMAND (gal/hr)	FUEL USED (gal/hr)	FUEL SAVED (gal/hr)
800	1	57.1	742.9	51.6	47.8	3.8
	2	114.2	685.8	51.6	44.8	6.8
	3	171.3	628.7	51.6	41.7	9.9
	4	228.4	571.6	51.6	38.6	13.0

	WIND SPEED (20 mph)					
DEMAND LOAD (kW)	#WG	WG (kW)	DG (kW)	FUEL DEMAND (gal/hr)	FUEL USED (gal/hr)	FUEL SAVED (gal/hr)
800	1	118.7	681.3	51.6	44.5	7.1
	2	237.4	562.6	51.6	38.2	13.4
	3	356.1	443.9	51.6	31.8	19.8
	4	474.8	325.2	51.6	25.4	26.2

	WIND SPEED (25 mph)					
DEMAND LOAD (kW)	#WG	WG (kW)	DG (kW)	FUEL DEMAND (gal/hr)	FUEL USED (gal/hr)	FUEL SAVED (gal/hr)
800	1	171.4	628.6	51.6	41.7	9.9
	2	342.8	457.2	51.6	32.5	19.1
	3	514.2	285.8	51.6	23.5	28.1
	4	685.6	114.4	51.6	16.6	35.0

	WIND SPEED (30 mph)					
DEMAND LOAD (kW)	#WG	WG (kW)	DG (kW)	FUEL DEMAND (gal/hr)	FUEL USED (gal/hr)	FUEL SAVED (gal/hr)
800	1	206.0	594.0	51.6	39.8	11.8
	2	412.0	388.0	51.6	28.8	22.8
	3	618.0	182.0	51.6	19.3	32.3
	4	824.0	126.0	51.6	17.1	34.5

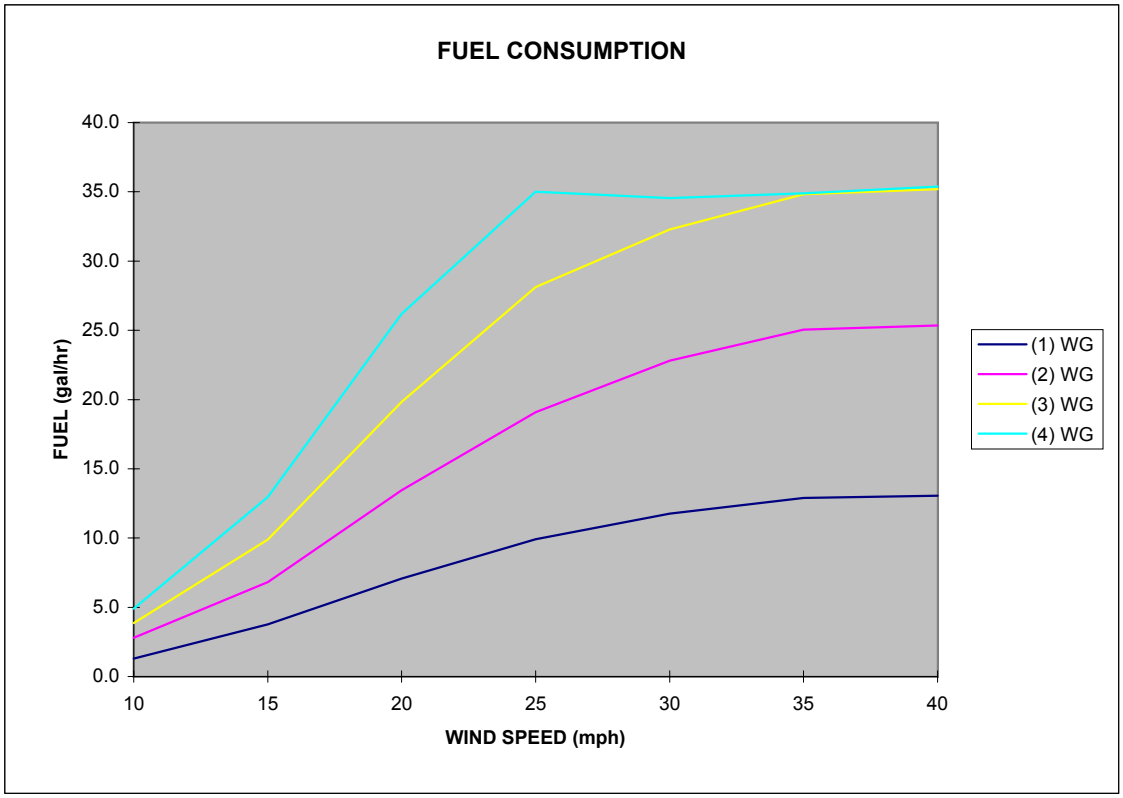
	WIND SPEED (35 mph)					
DEMAND LOAD (kW)	#WG	WG (kW)	DG (kW)	FUEL DEMAND (gal/hr)	FUEL USED (gal/hr)	FUEL SAVED (gal/hr)
800	1	227.0	573.0	51.6	38.7	12.9
	2	454.0	346.0	51.6	26.6	25.0
	3	681.0	119.0	51.6	16.8	34.8
	4	908.0	117.0	51.6	16.7	34.9

	WIND SPEED (40 mph)					
DEMAND LOAD (kW)	#WG	WG (kW)	DG (kW)	FUEL DEMAND (gal/hr)	FUEL USED (gal/hr)	FUEL SAVED (gal/hr)
800	1	230.0	570.0	51.6	38.5	13.1
	2	460.0	340.0	51.6	26.2	25.4
	3	690.0	110.0	51.6	16.4	35.2
	4	920.0	105.0	51.6	16.2	35.4

NREL: SAN CLEMENTE ISLAND

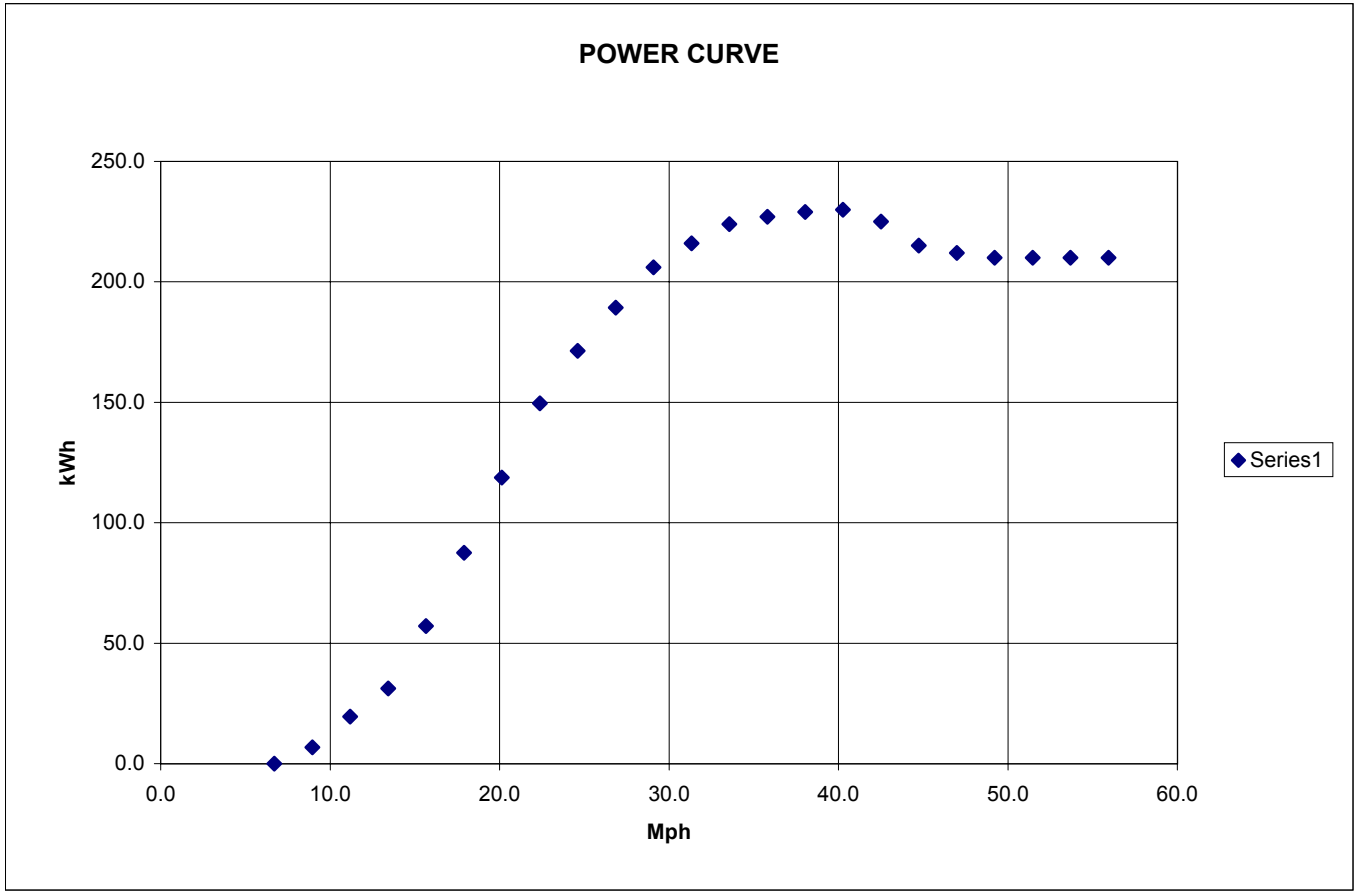
3 gal/ 75 kW =	0.04
4 gal/ 75 kW =	0.053333
5 gal/ 75 kW =	0.066667
6 gal/ 75 kW =	0.08
7 gal/ 75 kW =	0.093333

	(1) WG	(2) WG	(3) WG	(4) WG
10	1.3	2.8	3.9	4.9
15	3.8	6.8	9.9	13.0
20	7.1	13.4	19.8	26.2
25	9.9	19.1	28.1	35.0
30	11.8	22.8	32.3	34.5
35	12.9	25.0	34.8	34.9
40	13.1	25.4	35.2	35.4



POWER CURVE DATA
WIND GENERATOR: MODEL 225kW

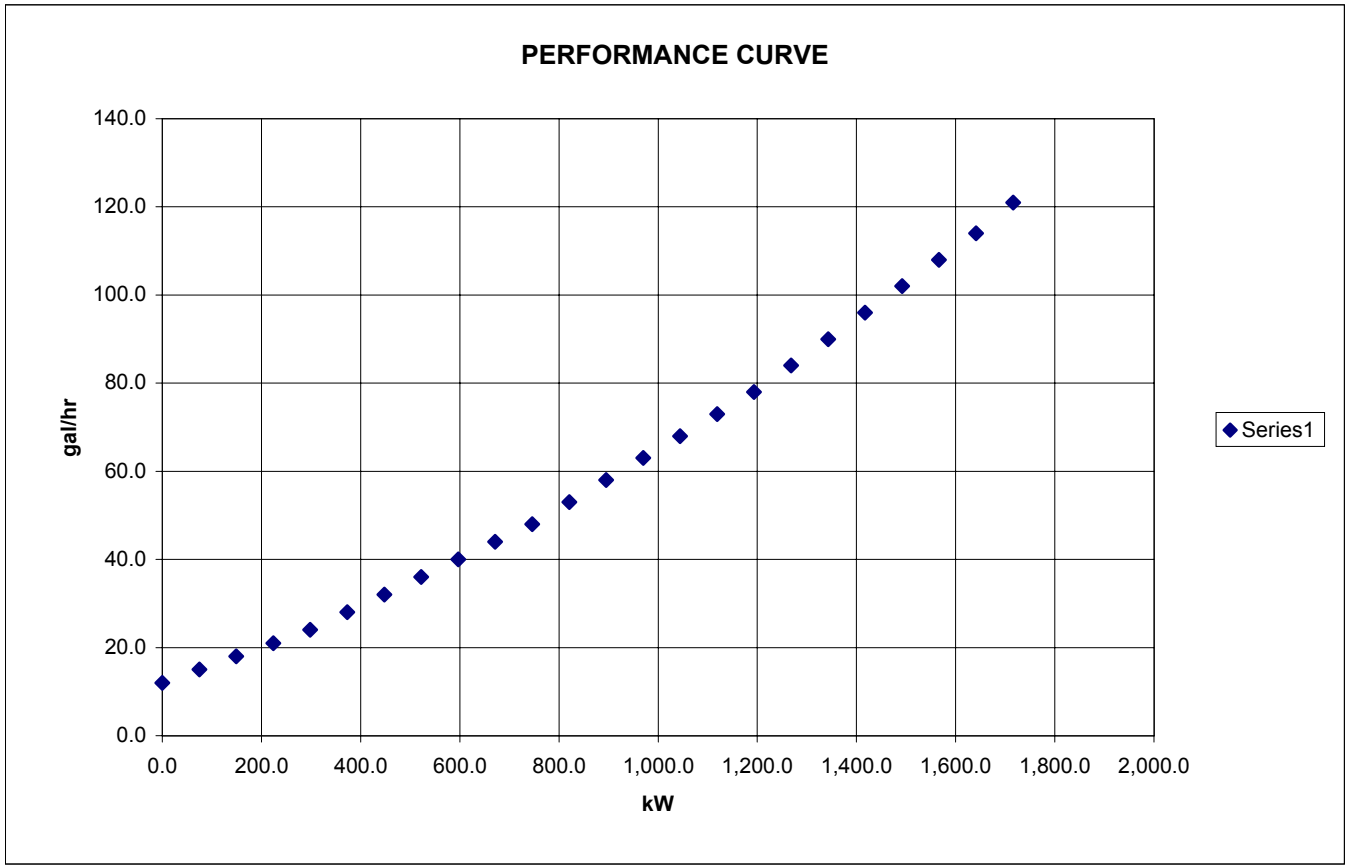
WIND SPEED	WIND SPEED	ELECTRIC POWER
m/s	Mph	kWh
3.0	6.7	0.0
4.0	8.9	6.8
5.0	11.2	19.5
6.0	13.4	31.2
7.0	15.7	57.1
8.0	17.9	87.6
9.0	20.1	118.7
10.0	22.4	149.6
11.0	24.6	171.4
12.0	26.8	189.3
13.0	29.1	206.0
14.0	31.3	216.0
15.0	33.6	224.0
16.0	35.8	227.0
17.0	38.0	229.0
18.0	40.3	230.0
19.0	42.5	225.0
20.0	44.7	215.0
21.0	47.0	212.0
22.0	49.2	210.0
23.0	51.5	210.0
24.0	53.7	210.0
25.0	55.9	210.0
>25	0.0	0.0



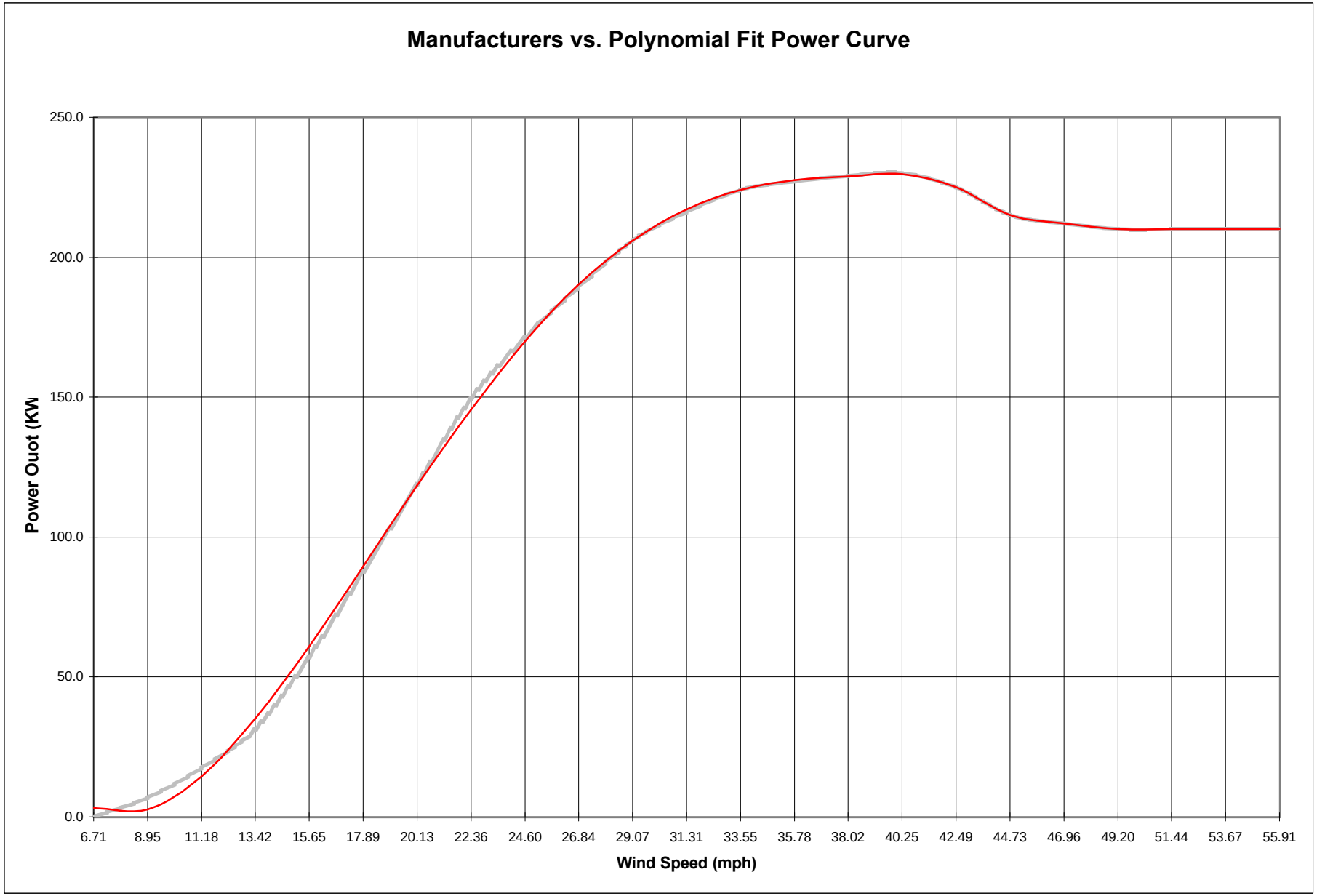
Mph=(m/s)*(2.237)

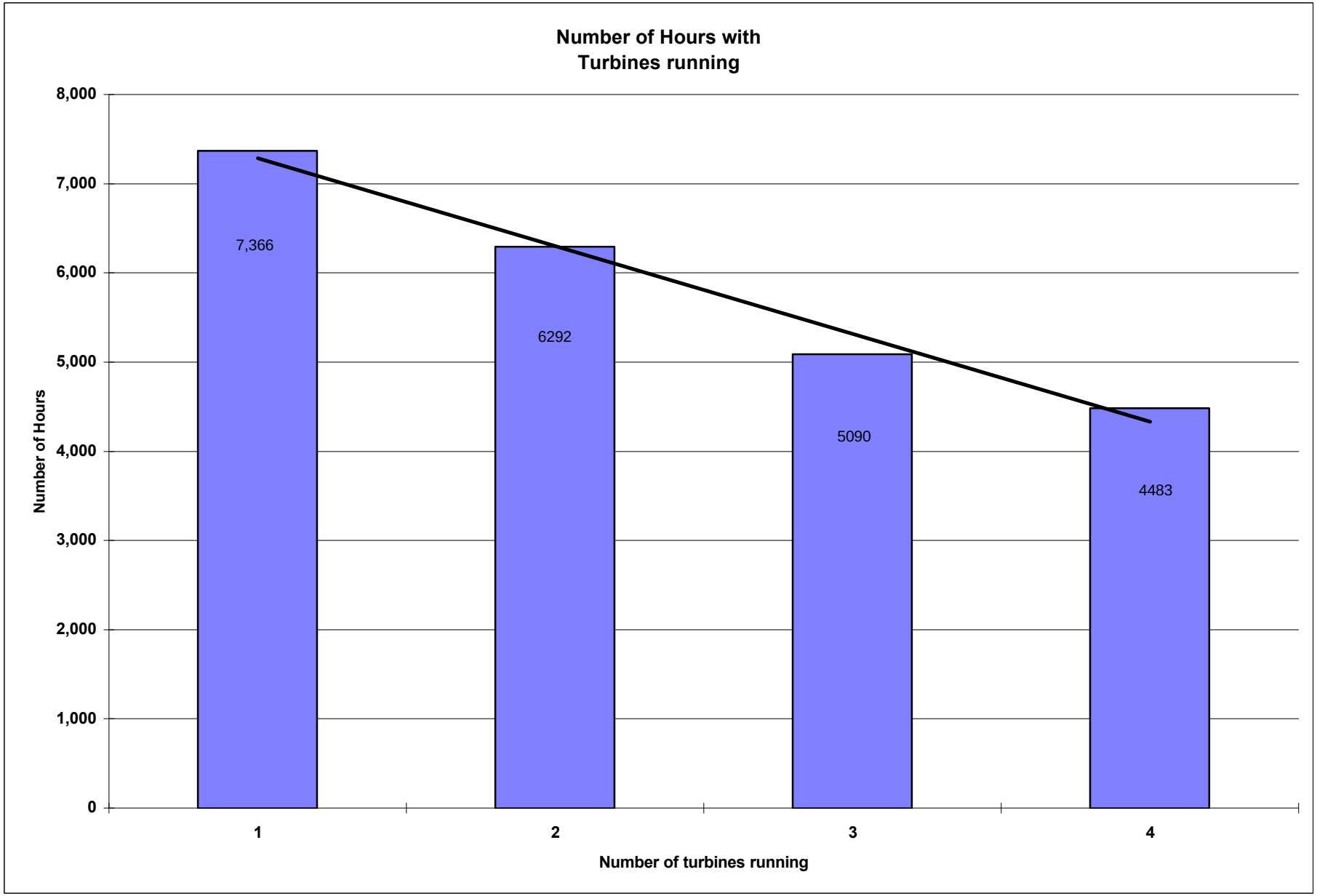
PERFORMANCE CURVE DATA
DETROIT DIESEL GENERATOR: MODEL 16V-149TI SCCC

POWER	POWER	FUEL
bph	kW	gal/hr
0.0	0.0	12.0
100.0	74.6	15.0
200.0	149.2	18.0
300.0	223.8	21.0
400.0	298.4	24.0
500.0	373.0	28.0
600.0	447.6	32.0
700.0	522.2	36.0
800.0	596.8	40.0
900.0	671.4	44.0
1,000.0	746.0	48.0
1,100.0	820.6	53.0
1,200.0	895.2	58.0
1,300.0	969.8	63.0
1,400.0	1,044.4	68.0
1,500.0	1,119.0	73.0
1,600.0	1,193.6	78.0
1,700.0	1,268.2	84.0
1,800.0	1,342.8	90.0
1,900.0	1,417.4	96.0
2,000.0	1,492.0	102.0
2,100.0	1,566.6	108.0
2,200.0	1,641.2	114.0
2,300.0	1,715.8	121.0



kW=bhp*0.746


Manufacturers vs. Polynomial Fit Power Curve
Power Ouot (KW
250.0
200.0
150.0
100.0
50.0
0.0
6.71
8.95
11.18
13.42
15.65
17.89
20.13
22.36
24.60
26.84
29.07
31.31
33.55
35.78
38.02
40.25
42.49
44.73
46.96
49.20
51.44
53.67
55.91
Wind Speed (mph)


Number of Hours with
Turbines running
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Number of Hours
7,366
6292
5090
4483
1
2
3
4
Number of turbines running

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13. ABSTRACT *(Maximum 200 words)*

This report provides an overview of the wind resource, economics and operation of the recently installed wind turbines in conjunction with diesel power for the Naval Air Landing Field (NALF), San Clemente Island (SCI), California Project.

The primary goal of the SCI wind power system is to operate with the existing diesel power plant and provide equivalent or better power quality and system reliability than the existing diesel system. The wind system is also intended to reduce, as far as possible, the use of diesel fuel and the inherent generation of nitrogen-oxide emissions and other pollutants.

The first two NM 225/30 225kW wind turbines were installed and started shake-down operations on February 5, 1998. This report describes the initial operational data gathered from February 1998 through January 1999, as well as the SCI wind resource and initial cost of energy provided by the wind turbines on SCI. In support of this objective, several years of data on the wind resources of San Clemente Island were collected and compared to historical data. The wind resource data were used as input to economic and feasibility studies for a wind-diesel hybrid installation for SCI.

14. SUBJECT TERMS
wind power, wind turbines, wind power and military applications, wind-diesel applications, Federal Energy Management Program

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