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APPROPRIATE SOLUTIONS FOR VARIOUS LEVELS OF ENERGY DEMAND

THE STATIC POWER PACK

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INTRODUCTION

The assessment of energy demand for communities which do not have electric power or those which have only intermittent power supply is a complex issue for administrators and designers.

Uncertainties such as population fluctuations, seasonal demand, increase in number and use of electrical appliances, and generally a new way of life, are difficult to predict.

Experience with Aboriginal communities in Western Australia shows that the problem can be approached by identifying different levels of supply according to the size of the community, how permanent it is and the cost or difficulty in obtaining fuel and maintaining diesel generators.

SINGLE DWELLINGS

Single isolated dwellings with basic unsophisticated requirements of lighting and refrigeration can be satisfied with solar photovoltaic energy systems.

Specially designed low energy 12V or 24V dc lights and refrigerators contribute to small systems of low cost.

It is presumed here that energy intensive applications such as hot water and cooking are provided by solar thermal, solid fuel or a gas source. Space heating and cooling is not available for such systems.

A degree of permanency is required for these systems, such as a reasonable structure to which solar panels, wiring and batteries can be attached (see Figure 1). The fact that the appliances are dc helps contain uncontrolled expansion and the low voltage makes it safe; no different to the electrical system of motor vehicles.

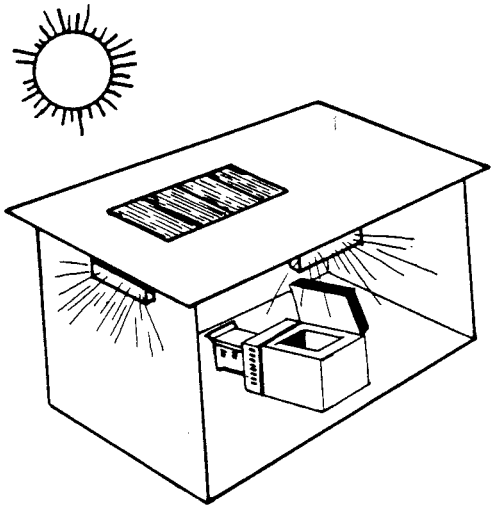


FIGURE 1

VERY SMALL COMMUNITIES

Aboriginal families groups of 30 of 40 people, typically represented by the Outstations or Homeland settlements, can be supplied with communal solar powered systems in which the electrical services are centralised in one structure which can generally act as the store.

Typical communal services are:

- Communication
- Lighting
- Refrigeration
- Television
- Vehicle battery charging
- Vehicle tyre inflation

A successful solution to providing the above services has been the Solar Pack. It consists of a transportable six metre shipping container with solar panel mounted on the roof, batteries, low energy refrigerators and freezers and radio communications inside (see Figure 2).

A large number of these units have been installed in the Australian outback, beginning in 1983. They have been operating continuously, with virtually no maintenance and zero fuel costs. This system has been particularly attractive as it is transportable and a few communities have shifted location, taking the Solar Pack with them.

Although these solar systems have a high up-front cost, they readily compensate for this with the provision of reliable services without the need of emergency maintenance or the urgency, difficulty and cost associated with fuel supplies.

The previous systems are quite adequate for loads of up to 20kWh/day.

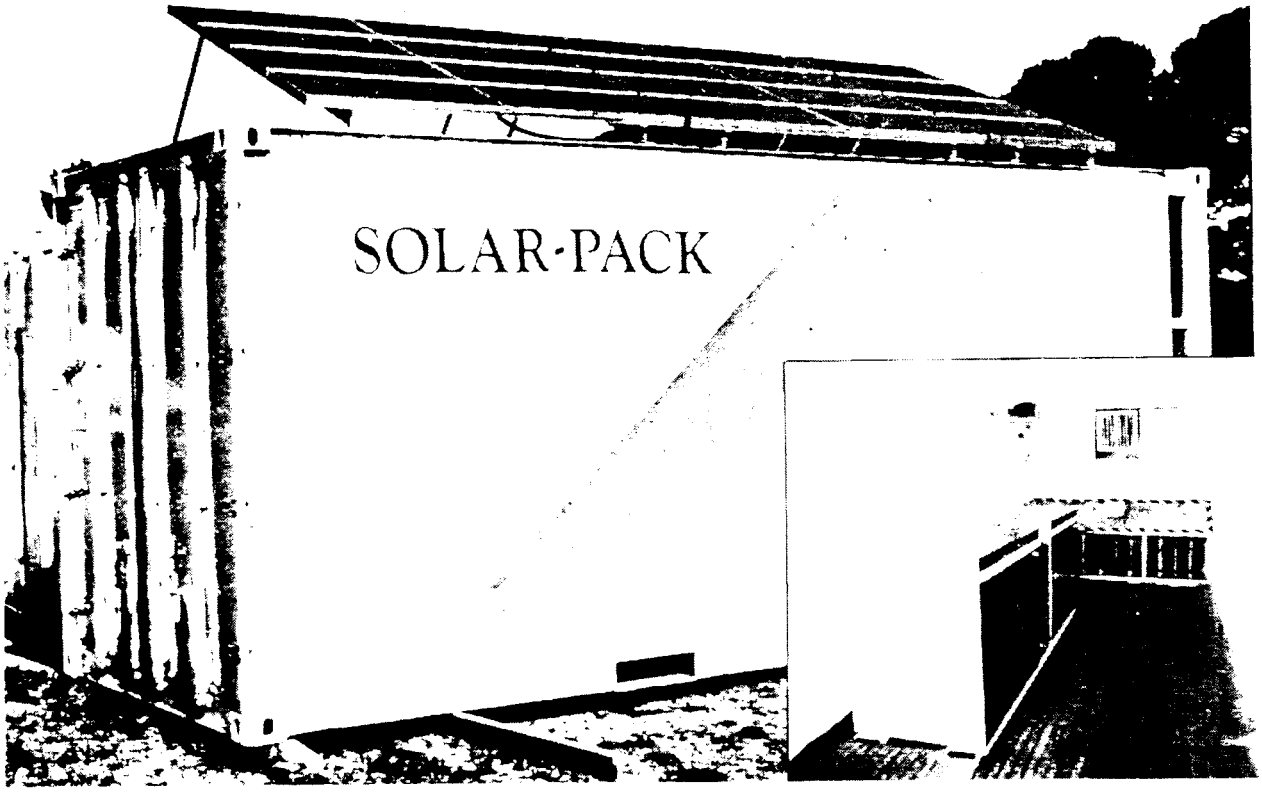


FIGURE 2

LARGER COMMUNITIES

For larger loads and where diesel fuel costs are under A60¢/litre diesel generator solutions are generally more cost effective.

The conventional approach for a stand alone diesel is to select the diesel generator set according to the peak load. A smaller set can be operated during low demand periods and a second larger set is reserved for the high demand period. Continuity of supply is assured as the alternative set is run while the first is down for whatever reason.

In small installations these systems are usually manually controlled by a trained operator. In larger communities utilities generally have stricter rules to assure an even safer supply with two small generators and a third larger unit.

LOADS

In most cases load profiles are of the 'double hump' type with large loads at around mid-day and the largest loads occurring from 6.00pm to 10.00pm. The loads from 11.00pm to 6.00am or 10.00am are generally very low (see Figure 3).

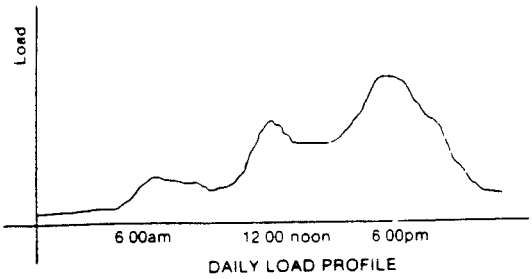


FIGURE 3

During periods of low loads the diesel generators will be poorly loaded with the consequences of poor fuel efficiency and low combustion temperatures. The low temperatures cause incomplete Combustion and carbon deposits (glazing) on the cylinder walls, causing premature engine wear. With manually controlled systems this problem can be exacerbated if the large engine is left operating continuously.

Figure 4 shows that a generator set operating at a 15% to 20% load/capacity ratio (most common operating point) runs at a fraction of its full load fuel efficiency.

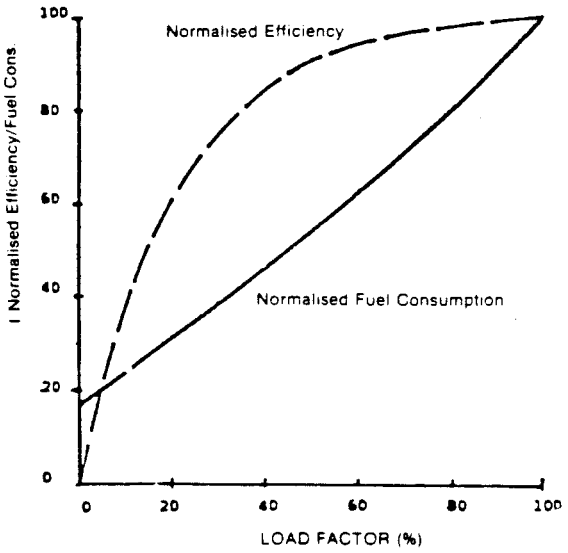


FIGURE 4

SOLUTIONS

To avoid the above problems diesel/battery/inverter systems have been developed so that the diesel generator operates well loaded by supplying the load and charging the batteries. During low load periods the batteries supply the load via an inverter. The diesel generator or the inverter have to supply the load independently.

The concept has had a limited success as the inverter has to be very large, supported by a similarly large battery bank. The system still requires the use of a large diesel generator set. The overall system efficiency is not very high.

The quality of power has also suffered in present designs which utilise modified square wave inverters. This type of wave form generally causes overheating in motors, thus reducing their efficiency and consuming more power, radio frequency noise, problems with fluorescent lighting, etc.

NEW DEVELOPMENTS

Advanced Energy System Pty Ltd (AES), a Western Australian company in collaboration with Murdoch University Energy Research Institute (MUERI) and Curtin University of Technology, through the National Energy Research Development and Demonstration Council (NERDDC) support, has developed the Static Power Pack (SPP) incorporating a sinewave inverter which produces a waveform comparable to that supplied by large power grids and has also developed the control technology to run the diesel generator in parallel with it (see Figure 5). Another novel feature of the AES sinewave inverter is that it is also a highly efficient battery charger.

These features have radically modified the sizing of diesel generator sets and battery banks. The peak loads can now be met by the diesel generator and the inverter together. Diesel generators have a maximum peaking capacity of 100% of the rated capacity whilst the inverter can peak to 200% (double) its capacity for short periods. So from a diesel maximum capacity of 100% this new system can now supply 210% regularly and 310% for short periods. For instantaneous power delivery the inverter can peak at 400% of its nominal capacity.

The effect is that smaller diesel generators can be utilised and considerably better fuel efficiency and engine life expectancy is achieved.

FIGURE 5

FLEXIBILITY

AES Static Power Pack can then cope with loads of zero (inverter operating only) to 310% (inverter and diesel operating in parallel) with excellent efficiency. This allows for a flexible power station which can cope effectively with growth and/or reduction in demand.

Figure 6 shows the daily load profile and the SPP output in its different operating modes:

- Inverter (INV) only
- Diesel generator (DG) only
- DG and INV in parallel
- DG and INV in parallel but INV operating as a battery charger

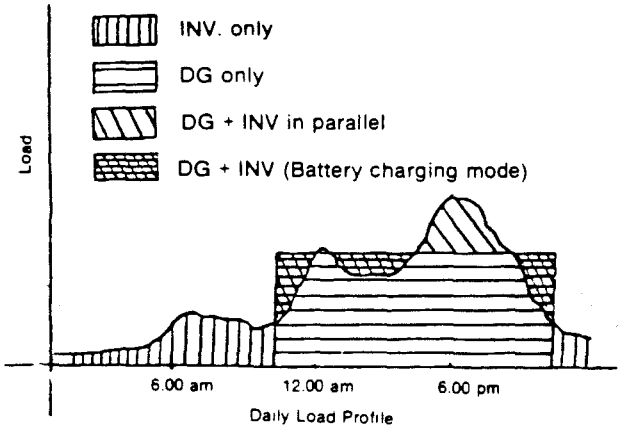


FIGURE 6

A key feature of this approach is that load sharing becomes possible and the even loading on the DG can be achieved for most of its operational time.

The SPP is fully automatic. It starts and stops the engine when required. There is no power interruption at any stage.

The SPP is flexible and allows the addition of more diesel generators, solar panels or wind generators with only minor changes to the operational programme.

When two engines are supplied the normal mode of operation is to start an alternate engine each time, thus ensuring uniform wear and high reliability. If the engines are supplied with electronic governors future system expansion can be achieved by operating both engines simultaneously. The SPP will synchronise the engines and parallel the inverter.

The batteries are of the dry cell type and do not require addition of distilled water. They are sealed for life.

RENEWABLE ENERGY

The SPP can be readily fitted with wind or solar power equipment. The battery and power conversion equipment are already incorporated.

The addition of renewable energy equipment will reduce the amount of fuel consumed and the operating time of the diesel generator set. Optimum engine performance is still maintained.

Wind and solar equipment are particularly useful to equalise the charge in batteries and to provide power to vital equipment (ie, refrigeration) when the community departs for extended periods. This is fairly typical with Aboriginal communities in Australia.

The solar equipment is modular and therefore more solar panels can be added as required.

ECONOMICS

The SPP achieves fuel and maintenance costs savings of around 50% whilst extending the engine life.

Payback periods of around three years are quite common. Operating costs should be determined separately for each case once loads, fuel costs and engine brand and sizes are known. If the fuel costs are higher than 60¢/litre the payback period is progressively lower than three years.

As the engines wear, their efficiency will drop and the economics will increasingly favour the SPP, compared to a stand alone diesel generator, because the engines run for less hours and at a high load to capacity ratio.

SUMMARY

The SPP provides a flexible power supply system which can cope with no loads to peak loads up to three times the diesel generator capacity.

Fuel and maintenance costs savings in the order of 50%, compared with stand alone diesel gensets, are normally achieved. Frequency of site visits are almost halved. The life of the equipment is almost doubled.

Silent operation (diesel off) is a normal daily occurrence for twelve to sixteen hours (normally occurring at night). This could be an attractive feature in the outback.

Fuel savings of 4,000 litres to 15,000 litres per year per community can be realised.

STATIC POWER PACKS (SPP) SIZES

		SPP 1	SPP 2	SPP 3
Nominal daily load	kWh	25	75	150
Load range	kWh/day	0-50	0-150	0-300
System peak load	kW	6	18	29
10 second peak load	kW	9	28	44
Diesel genet	kVA	4	10	17
	kW	3.2	8.4	14
Sinewave inverter	kW	3	10	15
Battery size	kWh	17	34	52
Battery voltage	V	48 or 100	110	110
Nominal operating diesel time	hrs/d	8	8	10
Phase		1	1	1
Solar or wind option: Size of equipment recommended	Solar kW	0.5 - 5.0	0.5 - 15	0.5 - 30
	Wind kW	0.3 - 3.0	2 - 10	2- 20

Notes:

1. Best performance are achieved at nominal sizes.
2. Operating times to diesel generators are approximate only and very load dependent.
3. When adding solar or wind options battery sizes must be revised.

ACKNOWLEDGMENTS

A considerable amount of the above work is the result of a dedicated research team from MUERI, Curtin and AES made possible with the financial support from NERDDC.

APPENDIX 1

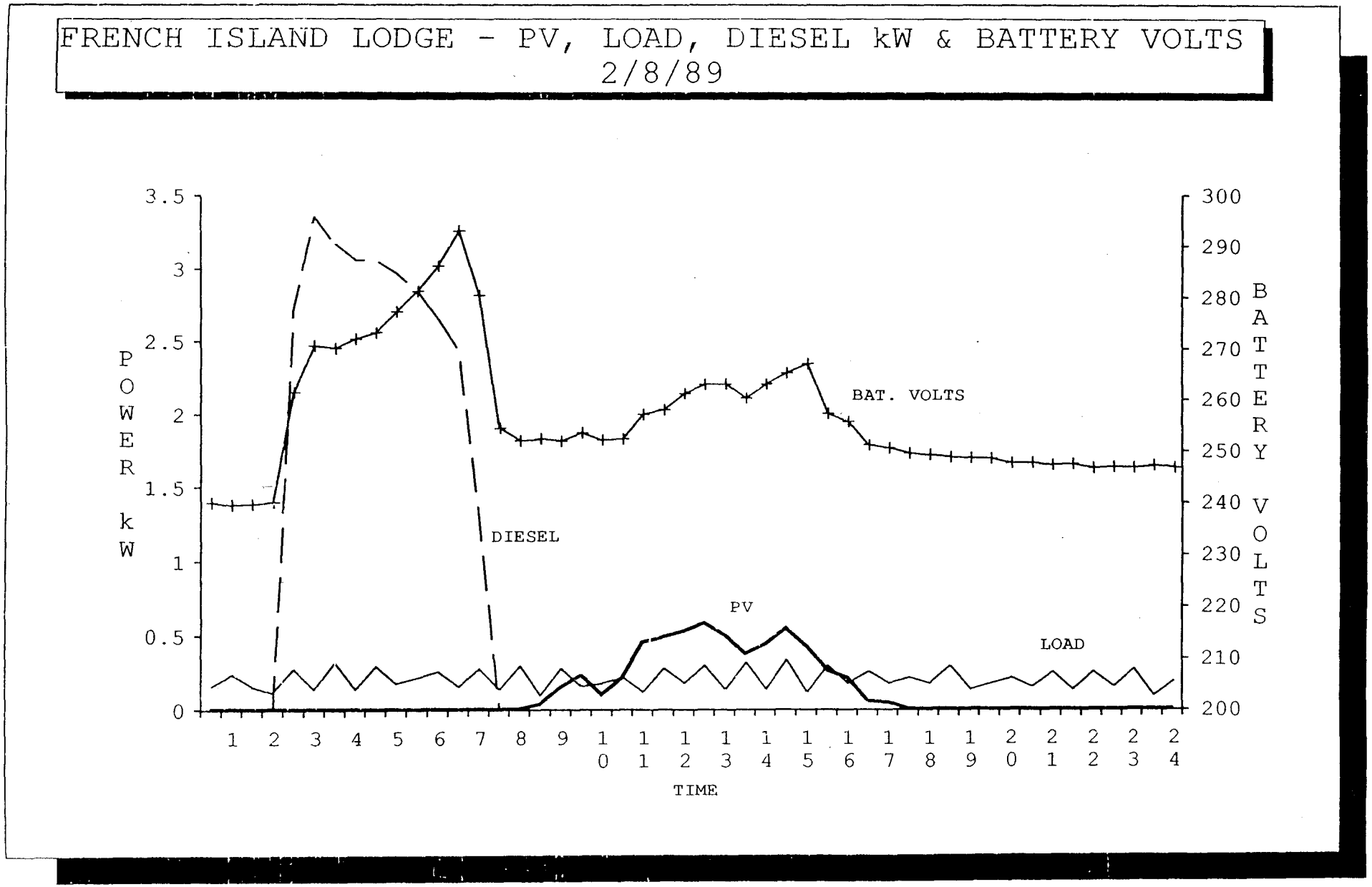
RENEWABLE ENERGY AUTHORITY FRENCH ISLAND LODGE - HYBRID ENERGY SYSTEM

DATE (units)	PV Array (kWh)	Diesel (kWh)	Diesel (hours)	Diesel (hr/day)	Diesel (kWh/hr)	Charge (kWh)	WindPV (%)	AC Load (kWh)	Av Load (kWh/day	Sys Eff (%)
22-Apr-88	290.2	0.0	5346	8.72	2.50			0	17.80	79.9%
29-Apr-88	302.2	165.0	5410	9.14	2.58	177.0	6.8%	131	18.71	74.0%
02-May-88	312.0	247.0	5442	10.67	2.56	91.8	10.7%	201	23.33	76.3%
09-May-88	320.1	402.0	5496	7.71	2.87	163.1	5.0%	324	17.57	75.4%
16-May-88	330.4	565.0	5552	8.00	2.91	173.3	5.9%	456	18.86	76.2%
23-May-88	340.9	720.0	5605	7.57	2.92	165.5	6.3%	583	18.14	76.7%
30-May-88	349.9	854.0	5657	7.43	2.58	143.0	6.3%	698	16.43	80.4%
06-Jun-88	368.0	1096.0	5748	13.00	2.66	260.1	7.0%	895	28.14	75.7%
13-Jun-88	379.3	1359.0	5832	12.00	3.13	274.3	4.1%	1121	32.29	82.4%
20-Jun-88	389.4	1570.0	5900	9.71	3.10	221.1	4.6%	1296	25.00	79.1%
04-Jul-88	411.5	1873.0	6011	7.93	2.73	325.1	6.8%	1527	16.50	71.1%
11-Jul-88	424.0	2042.0	6076	9.29	2.60	181.5	6.9%	1663	19.43	74.9%
18-Jul-88	436.4	2154.0	6120	6.29	2.55	124.4	10.0%	1756	13.29	74.8%
25-Jul-88	447.9	2298.0	6176	8.00	2.57	155.5	7.4%	1873	16.71	75.2%
02-Aug-88	460.3	2501.0	6251	9.38	2.71	215.4	5.8%	2042	21.13	78.5%
09-Aug-88	479.1	2695.0	6321	10.00	2.77	212.8	8.8%	2210	24.00	78.9%
15-Aug-88	494.7	2811.0	6363	7.00	2.76	131.6	11.9%	2308	16.33	74.5%
22-Aug-88	508.3	2967.0	6420	8.14	2.74	169.6	8.0%	2440	18.86	77.8%
29-Aug-88	525.4	3134.0	6488	9.71	2.46	184.1	9.3%	2588	21.14	80.4%
05-Sep-88	543.7	3273.0	6542	7.71	2.57	157.3	11.6%	2701	16.14	71.8%
12-Sep-88	560.8	3419.0	6596	7.71	2.70	163.1	10.5%	2822	17.29	74.2%
19-Sep-88	580.1	3554.0	6645	7.00	2.76	154.3	12.5%	2929	15.29	69.3%
26-Sep-88	599.9	3669.0	6685	5.71	2.88	134.8	14.7%	3047	16.86	87.5%
03-Oct-88	619.5	3774.0	6720	5.00	3.00	124.6	15.7%	3156	15.57	87.5%
10-Oct-88	641.9	3881.0	6761	5.86	2.61	129.4	17.3%	3245	12.71	68.8%
17-Oct-88	663.5	3974.0	6796	5.00	2.66	114.6	18.8%	3332	12.43	75.9%
24-Oct-88	685.5	4097.0	6840	6.29	2.80	145.0	15.2%	3446	16.29	78.6%
31-Oct-88	715.6	4270.0	6904	9.14	2.70	203.1	14.8%	3604	22.57	77.8%
07-Nov-88	743.7	4367.0	6938	4.86	2.85	125.1	22.5%	3710	15.14	84.7%
14-Nov-88	774.4	4480.0	6978	5.71	2.83	143.7	21.4%	3828	16.86	82.1%
21-Nov-88	791.1	4600.0	7016	5.43	3.16	136.7	12.2%	3917	12.71	65.1%
28-Nov-88	812.5	4724.0	7056	5.71	3.10	145.4	14.7%	4022	15.00	72.2%
05-Dec-88	831.8	4838.0	7096	5.71	2.85	133.3	14.5%	4122	14.29	75.0%
12-Dec-88	857.5	4889.0	7119	3.29	2.22	76.7	33.5%	4185	9.00	82.1%
19-Dec-88	880.5	5017.0	7181	8.86	2.06	151.0	15.2%	4241	8.00	37.1%
04-Jan-89	944.0	5310.0	7284	6.44	2.84	356.5	17.8%	4523	17.63	79.1%
09-Jan-89	960.1	5405.0	7323	7.80	2.44	111.1	14.5%	4582	11.80	53.1%
16-Jan-89	986.5	5497.0	7358	5.00	2.63	118.4	22.3%	4683	14.43	85.3%
23-Jan-89	1006.7	5610.0	7402	6.29	2.57	133.2	15.2%	4780	13.86	72.8%
30-Jan-89	1041.2	5762.0	7456	7.71	2.81	186.5	18.5%	4917	19.57	73.5%
06-Feb-89	1067.1	5916.0	7515	8.43	2.61	179.9	14.4%	5034	16.71	65.0%
13-Feb-89	1095.5	6094.0	7574	8.43	3.02	206.4	13.8%	5189	22.14	75.1%
20-Feb-89	1119.7	6266.0	7635	8.71	2.82	196.2	12.3%	5338	21.29	75.9%
27-Feb-89	1150.2	6390.0	7679	6.29	2.82	154.5	19.7%	5446	15.43	69.9%
20-Mar-89	1213.4	6858.0	7835	7.43	3.00	531.2	11.9%	5849	19.19	75.9%
29-Mar-89	1240.4	7145.0	7929	10.44	3.05	314.0	8.6%	6082	25.89	74.2%
05-Apr-89	1259.2	7284.0	7979	7.14	2.78	157.8	11.9%	6199	16.71	74.1%
10-Apr-89	1269.2	7359.0	8006	5.40	2.78	85.0	11.8%	6271	14.40	84.7%
17-Apr-89	1281.4	7488.0	8051	6.43	2.87	141.2	8.6%	6378	15.29	75.8%
360	991.2	7488	2705			8479.2		6378		
Daily Av.	2.8	20.8	7.51		2.77	23.6	11.7%	17.72		75.2%

APPENDIX 2

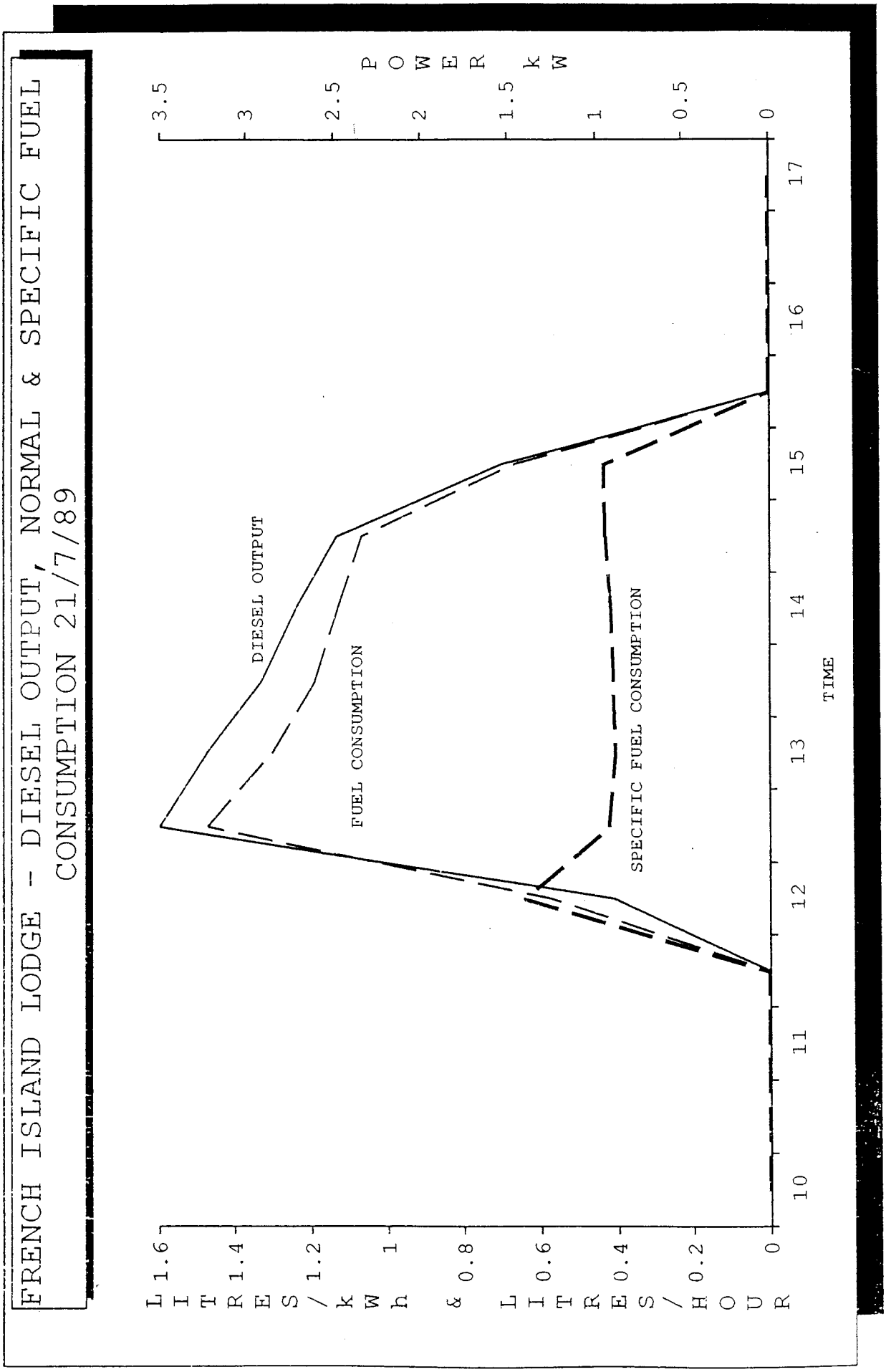
RENEWABLE ENERGY AUTHORITY — FRENCH ISLAND LODGE - HYBRID ENERGY SYSTEM

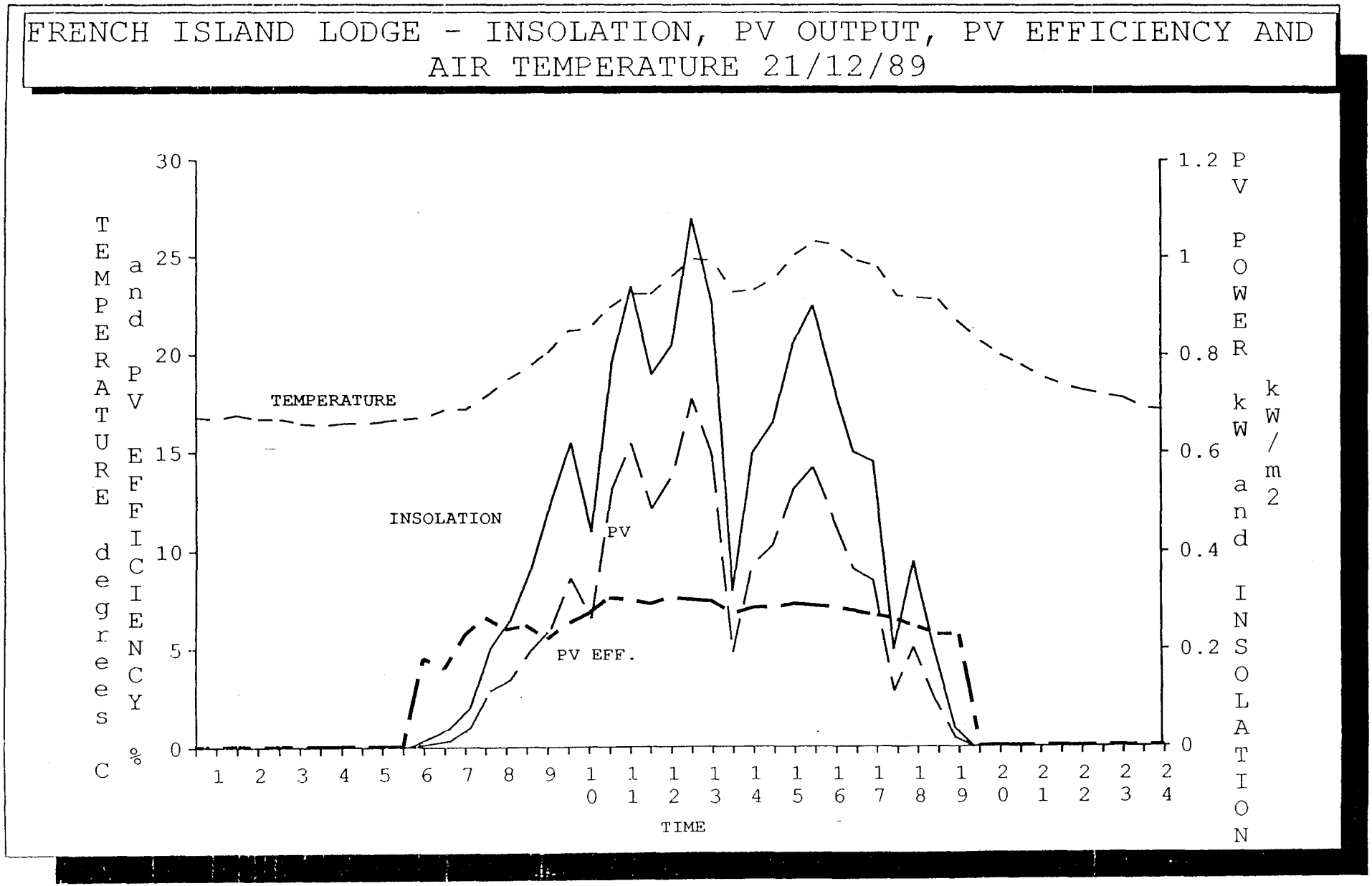
DATE (units)	PV Array (kWh)	Diesel (kWh)	Diesel (hours)	Diesel (hr/day)	Diesel (kWh/hr)	Charge (kWh)	WindPV (%)	AC Load (kWh)	Ht Pump (kWh)	Ht Pump (kWh/day	AC Load (kWh/day	Sys Eff (%)
17-Apr-89	1281.4	7488.0	8051	6.43	2.87	141.2	8.6%	6378	0.0	0.00	15.29	75.8%
01-May-89	1319.9	7797.0	8158	7.64	2.89	347.5	11.1%	6626	0.0	0.00	17.71	71.4%
08-May-89	1331.3	7908.0	8196	5.43	2.92	122.4	9.3%	6727	0.0	0.00	14.43	82.5%
15-May-89	1351.9	8014.0	8233	5.29	2.86	126.6	16.3%	6820	0.0	0.00	13.29	73.5%
22-May-89	1364.2	8152.0	8278	6.43	3.07	150.3	8.2%	6936	0.0	0.00	16.57	77.2%
05-Jun-89	1384.4	8401.0	8353	5.36	3.32	269.2	7.5%	7143	0.0	0.00	14.79	76.9%
09-Jun-89	1386.1	8487.0	8380	6.75	3.19	87.7	1.9%	7208	0.0	0.00	16.25	74.1%
16-Jun-89	1386.1	8590.0	8412	4.57	3.22	103.0	0.0%	7285	0.0	0.00	11.00	74.8%
23-Jun-89	1386.1	8655.0	8433	3.00	3.10	65.0	0.0%	7330	0.0	0.00	6.43	69.2%
30-Jun-89	1386.1	8720.0	8453	2.86	3.25	65.0	0.0%	7373	0.0	0.00	6.14	66.2%
07-Jul-89	1386.1	8806.0	8480	3.86	3.19	86.0	0.0%	7430	0.0	0.00	8.14	66.3%
14-Jul-89	1390.6	8911.0	8512	4.57	3.28	109.5	4.1%	7510	0.0	0.00	11.43	73.1%
21-Jul-89	1404.0	8946.0	8523	1.57	3.18	48.4	27.7%	7546	0.0	0.00	5.14	74.4%
28-Jul-89	1420.7	9029.0	8551	4.00	2.96	99.7	16.8%	7613	0.0	0.00	9.57	67.2%
04-Aug-89	1431.4	9073.0	8568	2.43	2.59	54.7	19.6%	7654	0.0	0.00	5.86	75.0%
11-Aug-89	1443.4	9143.0	8591	3.29	3.04	82.0	14.6%	7709	0.0	0.00	7.86	67.1%
18-Aug-89	1461.7	9181.0	8605	2.00	2.71	56.3	32.5%	7749	0.0	0.00	5.71	71.0%
25-Aug-89	1475.9	9272.0	8633	4.00	3.25	105.2	13.5%	7823	0.0	0.00	10.57	70.3%
01-Sep-89	1491.4	9338.0	8658	3.57	2.64	81.5	19.0%	7886	0.0	0.00	9.00	77.3%
08-Sep-89	1516.7	9387.0	8675	2.43	2.88	74.3	34.1%	7935	0.0	0.00	7.00	65.9%
15-Sep-89	1538.2	9457.0	8700	3.57	2.80	91.5	23.5%	8003	0.0	0.00	9.71	74.3%
22-Sep-89	1558.7	9513.0	8720	2.86	2.80	76.5	26.8%	8053	0.0	0.00	7.14	65.4%
29-Sep-89	1582.4	9603.0	8756	5.14	2.50	113.7	20.8%	8154	0.0	0.00	14.43	88.8%
06-Oct-89	1605.4	9722.0	8801	6.43	2.64	142.0	16.2%	8243	0.0	0.00	12.71	62.7%
13-Oct-89	1623.8	9821.0	8839	5.43	2.61	117.4	15.7%	8334	0.0	0.00	13.00	77.5%
20-Oct-89	1652.0	9911.0	8871	4.57	2.81	118.2	23.9%	8418	0.0	0.00	12.00	71.1%
27-Oct-89	1673.1	9994.0	8903	4.57	2.59	104.1	20.3%	8494	3.5	0.50	10.86	73.0%
03-Nov-89	1697.3	10063.0	8928	3.57	2.76	93.2	26.0%	8559	11.5	1.14	9.29	69.7%
10-Nov-89	1721.7	10156.0	8963	5.00	2.66	117.4	20.8%	8649	34.0	3.21	12.86	76.7%
17-Nov-89	1746.7	10224.0	8989	3.71	2.62	93.0	26.9%	8717	50.0	2.29	9.71	73.1%
24-Nov-89	1772.0	10362.0	9044	7.86	2.51	163.3	15.5%	8811	84.0	4.86	13.43	57.6%
01-Dec-89	1800.7	10447.0	9075	4.43	2.74	113.7	25.2%	8906	107.0	3.29	13.57	83.6%
08-Dec-89	1830.1	10505.0	9097	3.14	2.64	87.4	33.6%	8967	112.0	0.71	8.71	69.8%
15-Dec-89	1856.7	10593.0	9130	4.71	2.67	114.6	23.2%	9047	125.0	1.86	11.43	69.8%
22-Dec-89	1887.5	10676.0	9160	4.29	2.77	113.8	27.1%	9134	149.0	3.43	12.43	76.4%
29-Dec-89	1916.6	10758.0	9189	4.14	2.83	111.1	26.2%	9215	166.0	2.43	11.57	72.9%
05-Jan-90	1945.6	10872.0	9218	4.14	3.93	143.0	20.3%	9314	192.0	3.71	14.14	69.2%
12-Jan-90	1970.9	10985.0	9258	5.71	2.83	138.3	18.3%	9424	212.0	2.86	15.71	79.5%
19-Jan-90	1998.1	11063.0	9287	4.14	2.69	105.2	25.9%	9498	220.0	1.14	10.57	70.3%
26-Jan-90	2032.0	11110.0	9304	2.43	2.76	80.9	41.9%	9566	225.0	0.71	9.71	84.1%
02-Feb-90	2057.9	11247.0	9356	7.43	2.63	162.9	15.9%	9681	243.0	2.57	16.43	70.6%
09-Feb-90	2084.6	11334.0	9388	4.57	2.72	113.7	23.5%	9758	261.0	2.57	11.00	67.7%
16-Feb-90	2115.1	11404.0	9414	3.71	2.69	100.5	30.3%	9833	277.0	2.29	10.71	74.6%
23-Feb-90	2141.6	11488.0	9442	4.00	3.00	110.5	24.0%	9916	296.0	2.71	11.86	75.1%
02-Mar-90	2166.3	11575.0	9472	4.29	2.90	111.7	22.1%	9997	313.0	2.43	11.57	72.5%
09-Mar-90	2194.3	11713.0	9517	6.43	3.07	166.0	16.9%	10112	333.0	2.86	16.43	69.3%
16-Mar-90	2218.9	11818.0	9553	5.14	2.92	129.6	19.0%	10212	355.0	3.14	14.29	77.2%
23-Mar-90	2242.1	11947.0	9596	6.14	3.00	152.2	15.2%	10322	384.0	4.14	15.71	72.3%
30-Mar-90	2269.2	12050.0	9630	4.86	3.03	130.1	20.8%	10415	404.0	2.86	13.29	71.5%
06-Apr-90	2291.7	12119.0	9651	3.00	3.29	91.5	24.6%	10484	420.0	2.29	9.86	75.4%
13-Apr-90	2310.2	12196.0	9676	3.57	3.08	95.5	19.4%	10553	433.0	1.86	9.86	72.3%
20-Apr-90	2324.2	12323.0	9717	5.86	3.10	141.0	9.9%	10652	460.0	3.86	14.14	70.2%
27-Apr-90	2336.1	12410.0	9746	4.14	3.00	98.9	12.0%	10724	478.0	2.57	10.29	72.8%
375	1054.7	4922	1695			5976.7		4346	478			
Daily Av.	2.8	13.1	4.52		2.90	15.9	17.6%	11.59	2.53			72.7%



GRAPH 1
PV, LOAD, DIESEL POWER and BATTERY VOLTAGE versus TIME of DAY.

GRAPH 2
DIESEL OUTPUT, FUEL USE and SPECIFIC FUEL CONSUMPTION versus TIME of DAY.





GRAPH 3
INSOLATION, PV OUTPUT, PV EFFICIENCY and AIR TEMPERATURE versus TIME of DAY.