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Evaluation of Opportunities for Load Shifting With Fast Charging at Del Monte Foods

Technical Report

Evaluation of Opportunities for Load Shifting With Fast Charging at Del Monte Foods

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Final Report, October 2005

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PRODUCT DESCRIPTION

Fast charging of forklift batteries in warehouse facilities may allow companies to benefit from the load-leveling initiatives of electric suppliers. To achieve these benefits, forklift battery charging must be avoided during peak energy consumption periods. Unfortunately, the long run-times needed to achieve this goal may result in low battery states of charge (SOC) that adversely affect performance of forklifts with DC motors. However, forklifts are now available with AC motors whose performance does not vary with battery SOC. Use of such forklifts may make it possible to exploit load-leveling initiatives. This report compares fast charging of DC and AC motivated forklifts at a working Del Monte Foods warehouse to determine the feasibility of using AC motivated forklifts to support load-leveling initiatives.

Results & Findings

This report compares the performance of AC motivated forklifts to DC forklifts and also considers the other benefits of the AC machines. Various charge scenarios were explored to determine if a warehouse facility could take advantage of billing rate structures while using the AC machines. Savings in loads leveling and associated energy costs are maximized when charge cycles are staggered to avoid peak charging, but operational considerations make this goal difficult to attain. The AC machines in the demonstration achieved several run times of greater than 6 hours, but daily discharges cycles of 6 hours are not sustainable in a 24-hour, 3-shift operation because significant time is required to recharge the battery. Also, since the rate structure of the facility studied in this report is based on time-of-use rates that do not significantly discount off-peak charging, there is insufficient incentive to operate the forklifts during off-peak times. In this case, charging off peak would not result in significant cost savings to the end-user though it could reduce peak energy usage if used in a 1- or 2-shift operation.

The project demonstrated that the use of fast chargers and forklifts with AC motor drives lower energy and maintenance costs. Based on their work with various chargers and batteries, Del Monte Foods is moving toward the use of higher voltage (80V) batteries and forklifts with AC motors.

Challenges & Objectives

This report should be of interest to both electric suppliers interested in load leveling approaches and end-users interested in savings that may be realized from forklifts utilizing AC motors. The information provided in this report impacts all end-users whose forklifts fleets are used on a daily basis in both process industries and warehouse facilities. Continued work in this area should consider the latest available technology that may result in savings to the end-user while providing load-leveling opportunities to energy suppliers. Stakeholders interested in this work may include:

- End-users with large forklift fleets
- Electric energy suppliers
- Vendors of forklifts, batteries and battery chargers

Applications, Values & Use

This project showed that AC motivated forklifts can outperform their DC counterparts during daily operations. Since the AC forklifts do not utilize brushes, as do DC lifts, the AC lifts are less costly to maintain then their DC counterparts. Possible improvements in energy storage may include flow batteries or fuel cells as these technologies mature. Application of these future energy storage devices may allow forklifts to operate through times of peak energy consumption and provide means for faster recharge that can be sustainable in 3-shift 24-hour-a-day operations.

EPRI Perspective

EPRI guidance was instrumental at pulling together the resources and expertise necessary for the development of this report, but it was a team effort made possible by the close collaboration of power supplier, end-user, battery, charger, and forklift technical personnel.

Approach

The project team considered three charge scenarios at a warehouse facility associated with food processing. The scenarios compared the economics of fast-charging conventional DC lifts and lifts with AC motors. These scenarios were designed to:

- Evaluate charging of AC lift trucks during normal breaks and meal periods.
- Evaluate the impact of staggering the charging of AC lift trucks during peak periods
- Evaluate the possibility of eliminating fast charging of batteries during the peak periods as specified by the local power company, Pacific Gas & Electric.

The project team's economic analyses considered capital costs for equipment, annual costs for maintenance, and annual costs for electrical energy. The team based annual energy costs on facility past billing records and projections based on monitored data from fast chargers. To estimate energy and demand costs, customized spreadsheets incorporated billing data from the electric service provider with assumed charger demand and energy usage profiles.

Keywords

Fast charging
AC Forklifts
Staggered Charging
Warehouse
Peak Load Reduction

ABSTRACT

Forklifts are used extensively in warehouse operations to move and store product in the food processing industry. This report compares the performance of AC motivated forklifts to DC forklifts while considering the lower maintenance cost of the AC machines. Consideration is given to determine the capability of AC forklifts to avoid charging during peak electrical demand periods of the day. Various charge scenarios are explored to take advantage of billing rate structures.

ACKNOWLEDGMENTS

Robert Bellenger
EPRI Consultant
Bellenger Consulting

Mr. Bellenger's background and experience with off road electric vehicles provided added insight and guidance to the project. He was instrumental at pulling together the resources and expertise from the various organizations involved to provide the information necessary for the development of this report. We left 2004 with an irreplaceable hole when, Mr. Bob Bellenger, passed away late in the year. We miss him dearly.

Glen A. Lewis
Western Region Procurement Manager
Del Monte Foods - Western Region Office

Mr. Lewis acted as the key contact person at Del Monte Foods supporting the study necessary for this report. He provided plant level access to equipment and personnel and corporate access to accounting personnel required to define propane cost and equipment leasing costs. Mr. Lewis also provided contacts for suppliers of forklifts, battery, and charger equipment.

Bob Johnson
Plant Maintenance Manager
Del Monte Foods – Lathrop Facility

Mr. Johnson provided access to the Del Monte Foods Lathrop facility for AC charger monitoring, extracted BMI data from chargers, and scheduled lift operators to operate lifts according to specified scenarios.

Al Beliso
Technologist – Technical and Ecological Services
Pacific Gas and Electric Company

Mr. Beliso installed AC power monitors on battery chargers and collected data used to support the project.

Dan Pope
PG&E Account Services
Pacific Gas and Electric Company

Mr. Pope provided revenue and rate information from the various sites studied in this project. Mr. Pope also provided valuable support in understanding the unique nuances of the various rate structures.

Tony Marino
Sales Engineer
EnerSys, Inc.

Mr. Marino provided technical data regarding batteries being used at the plants studied.

Phil Waddy
Product Support Representative
Pacific Material Handling Solutions dba Yale-Pacific, Inc.

Mr. Waddy provided technical data regarding all types of forklifts considered in the project. He provided comparative data regarding maintenance costs between ICE, AC and DC motivated lifts.

Larry Hayashigawa
Product Manager
AeroVironment Inc.

Mr. Hayashigawa provided technical data regarding the fast chargers studied in the project. He also provided BMID and E-meter data important to understanding battery charge and discharge cycles along with his expertise and telephone support time necessary to interpret the data he provided.

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1
INTRODUCTION

Background

During 2003 EPRI-PEAC completed a project to evaluate fast charging opportunities at Del Monte Foods[1]. The project considered four charge scenarios at a food processing facility to determine the economics of fast charging compared to conventional charging. Two of the scenarios involved conventional charging methods and the remaining two addressed fast charging methods. One scenario for each charging method reduced the charging demand by minimizing the number of chargers being utilized at any time during the peak times as specified by energy service provider (PG&E).

The economic analysis considered capital costs for equipment, annual costs for maintenance, and annual costs for electrical energy. Annual energy costs were based on facility past billing records and projections from monitored data for conventional and fast chargers. To estimate energy and demand costs, customized spreadsheets incorporated billing data from the PG&E with assumed charger demand and energy usage profiles were developed and utilized.

Resulting from their investigations of various chargers and lifts, Del Monte Foods is proceeding with plans to use AC motor driven lift trucks that operate with an 80V battery system. The higher voltage batteries charge faster and operate cooler then their lower voltage (48V) fast charge counterparts. Besides having reduced maintenance cost (no brushes), the AC motor forklifts provide quicker response then traditional DC motor forklifts. Additionally, AC forklifts motive and lifting performance does not vary with battery SOC (between 80% and 20% SOC). With conventional DC units, as the battery discharges the lift trucks performance becomes slower and more sluggish.

Objectives

The purpose of this project is show how the advantages of fast charged batteries and AC driven forklifts may be combined to permit operations without the need for charging during peak billing periods affectively shifting loads. Pursuant to this purpose, the following objectives are addressed.

- Evaluate the impact of three charging scenarios with AC Forklifts on warehouse operations at Del Monte Foods.

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1 *Evaluation of Opportunities for Fast Charging Applications at Del Monte Foods*, EPRI, Palo Alto, CA: 2004. 1002237.

1. Evaluate charging of AC lift trucks during normal breaks and meal periods.

2. Evaluate the impact of staggering the charging of AC lift trucks during peak periods. This will be accomplishing by shifting breaks and meal periods to minimize the number of lift trucks charging at any time.

3. Evaluate the possibility of eliminating fast charging of batteries during the peak periods as specified by PG&E.

- Gather cost data associated with chargers, batteries, and AC lift trucks to support technical reporting of economic analysis.
- Provide a technical report comparison results from AC lifts with previous results from DC lifts evaluated in the 2003 project[2] at Del Monte Foods.

Approach

A project team involving Del Monte Foods warehouse management, PG&E, AeroVironment EPRI PEAC and EPRI implemented this project. Del Monte Foods warehouse management provided facility access and operational support necessary to implement the various charge scenarios. PG&E collected AC power data at the supply terminals of each of the chargers involved in the study. AeroVironment collected data from the Battery Monitor and Identifier (BMID) installed on the test battery packs during the test period.

EPRI PEAC collected the AC monitoring data and the BMID data corresponding to the charging scenarios. The data was utilized in customized spreadsheets to perform simple economic analysis of the lift trucks, chargers, and batteries used in this test. Some of the data was also imported into PQView®[3], for statistical analysis and trend plotting purposes. The results of these analyses are presented in this report along with a comparison to the results from previous work at Del Monte Foods.

2 *Evaluation of Opportunities for Fast Charging Applications at Del Monte Foods,* EPRI, Palo Alto, CA: 2004. 1002237.

3 PQView® is Power Quality Monitoring and Analysis software developed under an EPRI managed project.

2
DATA COLLECTION

Two sets of data were collected in support of this project. The AC supplies to each charger were monitored by PG&E while battery data was collected by AeroVironment. Table 2-1 provides a cross reference of battery monitoring data to the AC charger data collected.

Table 2-1
Cross reference of battery monitoring data with Charger AC monitors

Charger BMID Data					Power Monitor Data		
Charger No	Location	Charger SN	DT Start	DT End	Monitor SN	DT Start	DT End
1	indoors	00798	8/2/2004 17:24:00	9/24/2004 7:59:31	0000102	8/4/2004 14:58:34	9/17/2004 7:09:07
2	outdoors left	00796	7/15/2004 11:31:12	9/24/2004 2:03:50	0000103	8/11/2004 11:26:53	9/17/2004 6:25:55
3	outdoors middle	00802	8/3/2004 9:27:22	9/20/2004 18:01:26	0000101	8/4/2004 14:55:41	9/17/2004 6:27:22
4	outdoors right	00816	9/10/2004 15:50:24	9/24/2004 2:02:24	0000104	8/5/2004 10:06:14	9/17/2004 7:23:31
NA	indoors 48V	NA	NA	NA	BE80240	8/5/2004 9:40:19	9/17/2004 8:11:02

AC Charger Data

PG&E collected AC power data at the supply terminals of each of the chargers involved in the study. The time stamped AC power data as recorded in 30 second intervals. Table 2-2 presents a sample of the AC data received from PG&E.

Table 2-2
Raw AC data sample

Record Date	Record End Time	Chan 1 Avg. Volts	Chan 1 Avg. Amps	Chan 2 Avg. Volts	Chan 2 Avg. Amps	Chan 5 kW Hours	Chan 5 Avg. kW	Chan 5 Avg. PF
9/1/2004	21:24:00	489.7	1.01	486.4	0.8	0.001	0.164	0.2
9/1/2004	21:24:30	489.6	1.01	486.3	0.8	0.001	0.165	0.2
9/1/2004	21:25:00	489.5	1.19	486.2	1.09	0.003	0.412	0.41
9/1/2004	21:25:30	488	19.4	484.8	19.73	0.133	15.934	0.97
9/1/2004	21:26:00	487.8	22.98	484.7	23.15	0.157	18.823	0.97
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.

The raw data was reformatted and calculations performed to develop a text file for import into PQView®. The following calculations were performed on each sample:

- Three phase apparent power (VA),
  S Fund ALL = V RMS AB * I RMS A + V RMS CA * I RMS A

- Three phase real power (W),
  P ALL = S Fund ALL * PF ALL
- Energy consumed each sample (Whr),
  P Integrated ALL = P ALL * dt,
  where dt is the duration in hours between sample "n" and sample "n-1".

Table 2-3 provides a sample of the data resulting from the above calculations to the raw data as imported into PQView®.

Table 2-3
AC data sample imported into PQView®

[PQView SteadyState]
Charger 1

Time	V RMS AB	I RMS A	V RMS CA	I RMS C	PF ALL	S Fund ALL	P ALL	P Integrated All
9/1/2004 21:24:00	489.7	1.0	486.4	0.8	0.20	883.717	176.743	1.472862
9/1/2004 21:24:30	489.6	1.0	486.3	0.8	0.20	883.536	176.707	1.472560
9/1/2004 21:25:00	489.5	1.2	486.2	1.1	0.41	1112.463	456.110	3.800915
9/1/2004 21:25:30	488.0	19.4	484.8	19.7	0.97	19032.304	18461.335	153.844457
9/1/2004 21:26:00	487.8	23.0	484.7	23.2	0.97	22430.449	21757.536	181.312796
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.

The data from all the AC monitors were imported into PQView®, allowing a common platform for plotting trends and performing statistical analysis. Figure 2-1 provides a trend of the three phase power for Charger 1 during November 2004.

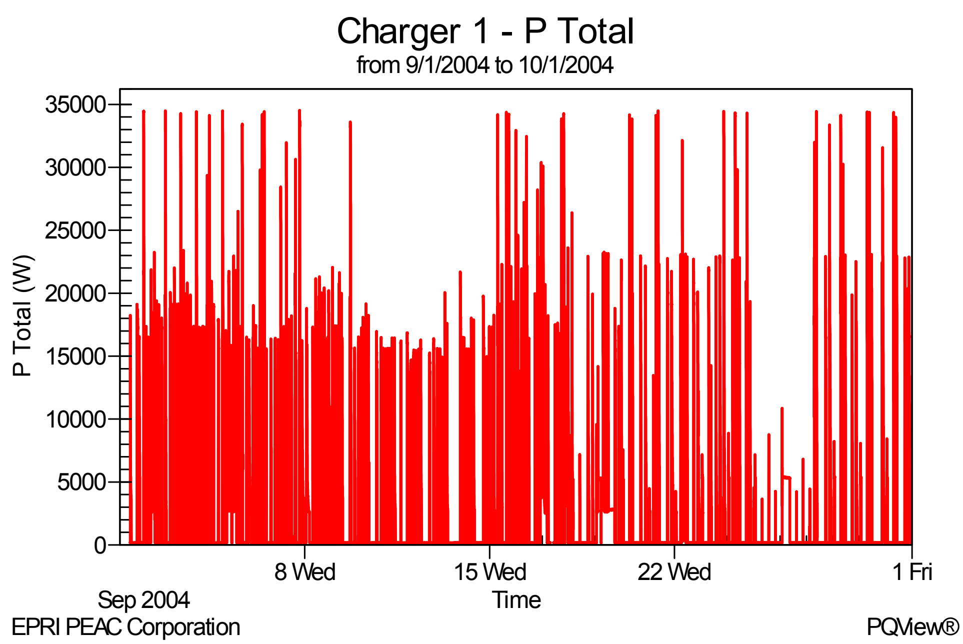

Figure 2-1
Trend of three phase power of Charger #1

Table 2-4 provides the statistical basis for projecting average power consumption per charge.

Table 2-4
Power Consumption Report From PQView® data

Integrated Power Statistics					
Date Range:	9/17/2004 8:58:34 AM - 9/23/2004 9:24:29 PM				
Data Filters:	Records with Integrated Power values >		9.9978	Wh	
Charger:	**1**	**2**	**3**	**4**	**1 - 4**
Count:	3188	1248	687	416	5539
Minimum	12.52	9.998	10.07	28.69	9.998
Average	153.4	101.6	104.9	92.95	131.2
Maximum	574.9	563.9	379	378.5	574.9
Range	562.3	553.9	368.9	349.8	564.9
Standard Deviation	122.8	102	96.41	55.76	114.3
CP25 (Q1)	50.73	54.4	54.79	52.17	54.32
CP50 (Q2)	95.71	56.01	55.33	70.82	79.65
CP75 (Q3)	229.4	95.33	99.34	113.4	180
Semi-Interquartile Range	89.36	20.46	22.27	30.63	62.82
CP5	44.26	49.2	53.7	49.61	44.9
CP95	382	345.3	364.3	212.6	372.2
Accumulated (Wh)	489039.2	126796.8	72066.3	38667.2	726716.8

DC Battery Data

The AeroVironment charging systems used in this study have data collection systems. These Battery Monitor and Identifier (BMID) systems allow the charger to automatically identify the battery being charged during each charge cycle. Some of the following time-stamped data includes:

- Battery ID
- Battery DC voltage levels at beginning and ending of each charge.
- Battery Peak charging currents
- State of charge (SOC) at beginning and ending of each charge
- Energy (Ahrs) supplied to the battery
- Battery temperature levels

Table 2-5 represents a sample of the raw BMID data.

Table 2-5
Raw BMID data sample

Battery ID	Start Date	Start Time	End Date	End Time	Start Volts	End Volts	End Current	Max Current	Start SOC	End SOC	Start Temp	End Temp	Ahrs Returned	Battery Type	Num Cells	Battery Capacity	Charger No
1	09/17/04	8:58:57	09/17/04	12:06:04	82.1	96	31.2	251.3	50.4	100	73	102	261	1	40	700	2
1	09/17/04	18:06:27	09/17/04	18:09:38	85.3	96.1	30.5	176.3	83.2	100	100	100	2	1	40	700	2
1	09/18/04	3:54:17	09/18/04	4:35:14	83.6	97	31	280.8	66	100	91	87	61	1	40	700	2
1	09/18/04	4:35:14	09/18/04	5:05:33	97	99.1	31.5	31.9	100	100	87	87	15	1	40	700	2
1	09/18/04	11:05:57	09/18/04	11:08:00	85.2	97.6	29.1	156.5	82.8	100	78	78	1	1	40	700	2
1	09/18/04	17:08:24	09/18/04	17:10:12	85.1	97.6	29.3	152.5	81.3	100	78	78	1	1	40	700	2
1	09/18/04	23:10:37	09/18/04	23:12:16	85	98.1	29.3	150.4	80.6	100	71	69	1	1	40	700	2

A Statistical Summary of the BMID data is presented in Table 2-6.

Table 2-6
Statistical Summary of BMID Data

Date Range:	**BMID Channels:**									
From: 9/17/2004 8:58:34										
To: 9/23/2004 21:24:29	**Start**	**End**	**End**	**Max**	**Start**	**End**	**Change**	**Start**	**End**	**Ahrs**
Events: 171	**Volts**	**Volts**	**Current**	**Current**	**SOC**	**SOC**	**SOC***	**Temp**	**Temp**	**Returned**
Minimum	80.8	83.5	0.0	0.0	**39.8**	56.6	0.0	64.0	64.0	0.0
Average	86.2	96.5	52.2	181.2	79.3	92.9	13.7	92.1	94.7	54.7
Maximum	98.5	106.1	216.8	281.5	100.0	100.0	**60.2**	125.0	123.0	337.0
Range	17.7	22.6	216.8	281.5	60.2	43.4	60.2	61.0	59.0	337.0
Standard Deviation	4.7	2.8	47.6	94.2	15.9	12.0	12.9	15.6	15.7	62.5
CP1	81.6	89.6	15.2	22.3	**47.1**	57.9	64.0	64.0	0.0	1.0
CP5	81.9	93.5	26.8	32.0	52.3	66.8	0.0	68.0	68.5	0.5
CP25 (Q1)	83.5	95.4	30.2	103.8	67.6	86.6	2.0	78.0	83.0	5.0
CP50 (Q2)	84.5	96.3	31.1	208.2	80.6	100.0	11.8	93.0	98.0	33.0
CP75 (Q3)	85.9	97.5	44.4	280.1	97.3	100.0	19.7	104.0	106.0	78.0
CP95	97.5	102.4	175.7	281.1	100.0	100.0	39.2	116.0	120.0	192.5

* Change in SOC was calculated from recorded data.

A few observations may be made from Table 2-6. The minimum state of charge was 39.8%. Further analysis reveals that this SOC occurred after a previous run-down from a 76% SOC level. Only 1 % (CP1 or Cumulative Probability) of all charge start SOC's were at or below 47.1%. Assuming this SOC level occurred after running down from 100% SOC, then it may be possible to only charge batteries to 85% SOC allowing for higher charging efficiencies. If charging to 85% is not accepted then lower Ahr batteries may be utilized to reduce capital costs associated with battery purchases. The maximum change in SOC during a charge is 60.2%. Detailed analysis reveals that this change resulted in a battery with an ending SOC of 100%. Again, this suggests that it may be possible to only charge batteries to 85% SOC or lower Ahr batteries may be utilized to reduce capital costs.

Further manipulation of the BMID data allows for the projection of battery SOCs at the start and end of each charge cycle as illustrated for Battery 7 in Figure 2-2.

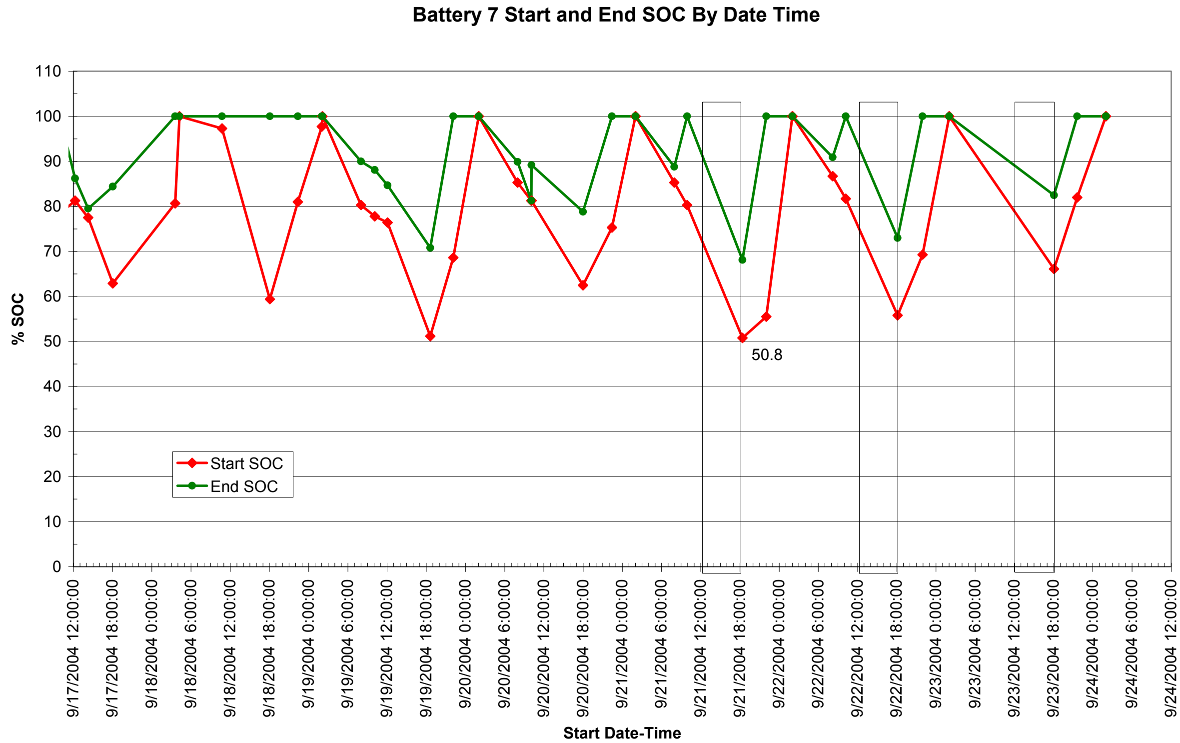

Figure 2-2
Charge cycle SOC trend for Battery 7

Figure 2-2 demonstrates that the AC lifts at the Del Monte Hanford facility with 700 Ahr, 80V batteries, should be able to operate daily through the 6 hours when cost of energy is highest without affecting operations. Forklift operator interviews indicate that no adverse operating conditions were experienced near the end of the 6 hour run cycles. Similar charts for batteries 1, 2, 3, 4, and 8 also support off peak charging. Battery 5 does not show any six hour run times. Based on SOC levels at end of run times, battery 5 should support off peak only charging. There is no data from battery 6 to analyse.

Due to the short production season insufficient data could be collected at the Del Monte Hanford warehouse facility. Consequently testing and data collection was moved to the Del Monte Lathrop warehouse. Several days of data was collected from the battery charger tracking battery states of charge (SOC) levels. During the data collection period the operators were asked to operate the vehicle without charging for at least 6 hours to determine the performance of the AC forklift at low SOC levels and to show that the AC forklift could operate through peak energy demand periods typically from 12:00 PM to 6:00 PM. The SOC data collected is charted in Figure 2-3.

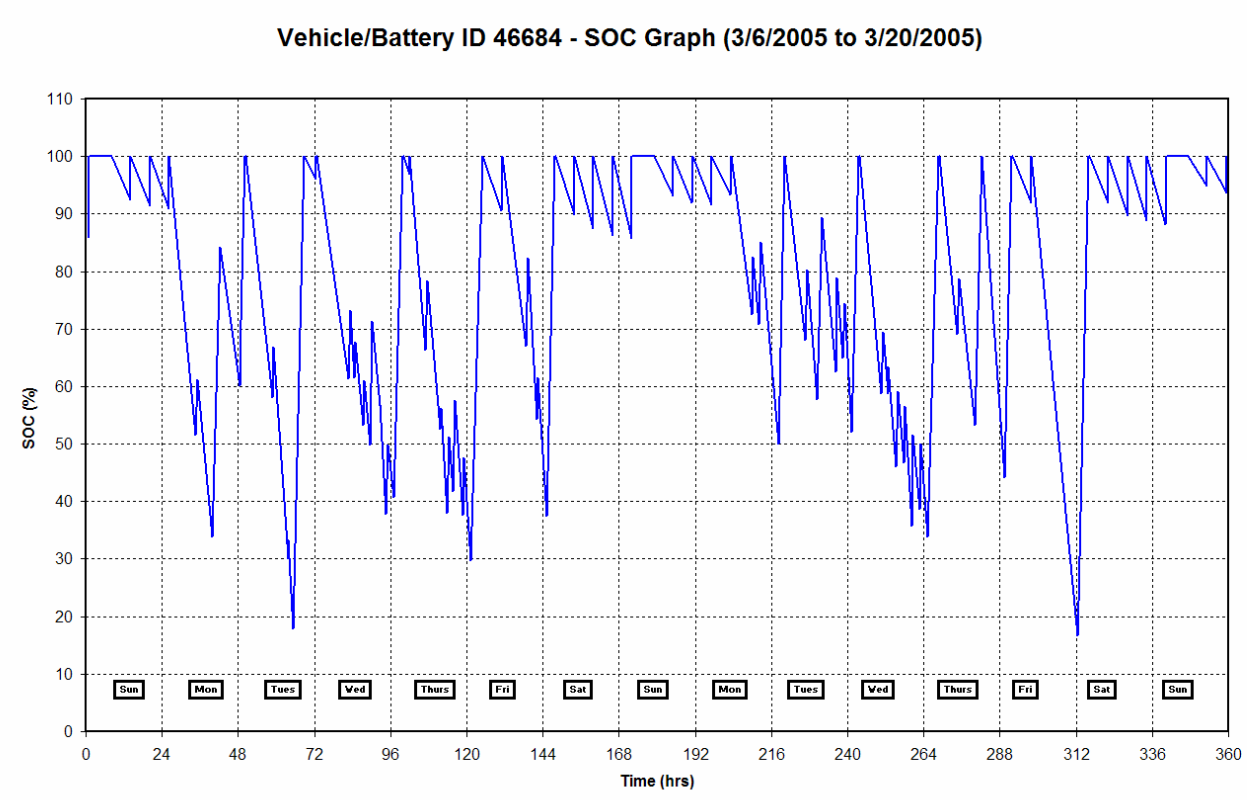

Figure 2-3
AC Forklift Battery States of Charge (SOC)

Several discharge cycles greater than 6 hours were achieved suggesting the vehicle could be operated through peak demand periods. However, in a 24 hour, 3 shift operation, daily discharge cycles of 6 hours is not sustainable as significant time is required to recharge the battery. For instance, in Figure 2-3, between hours 297 and 312 the battery discharged from 100% SOC down to 16.7% SOC. This represents a discharge rate of 6.22% SOC per hour. The following charge cycle required 3.6 hours to reach 100% SOC representing a charge rate of 23.1% SOC per hour. Similar calculations were performed on each charge and discharge cycle below 80% SOC to determine the average discharge and charge rates presented in Table 2-7. Only the data below 80% SOC were considered to eliminate error that may result from forklift ideal time.

Table 2-7
AC Forklift Battery Average Discharge and Charge Rates

Average Rate For;	%SOC/Hour
Discharge:	6.79
Charge:	23.54

Using the data from Table 2-7, daily SOC levels may be projected as shown in Figure 2-4.

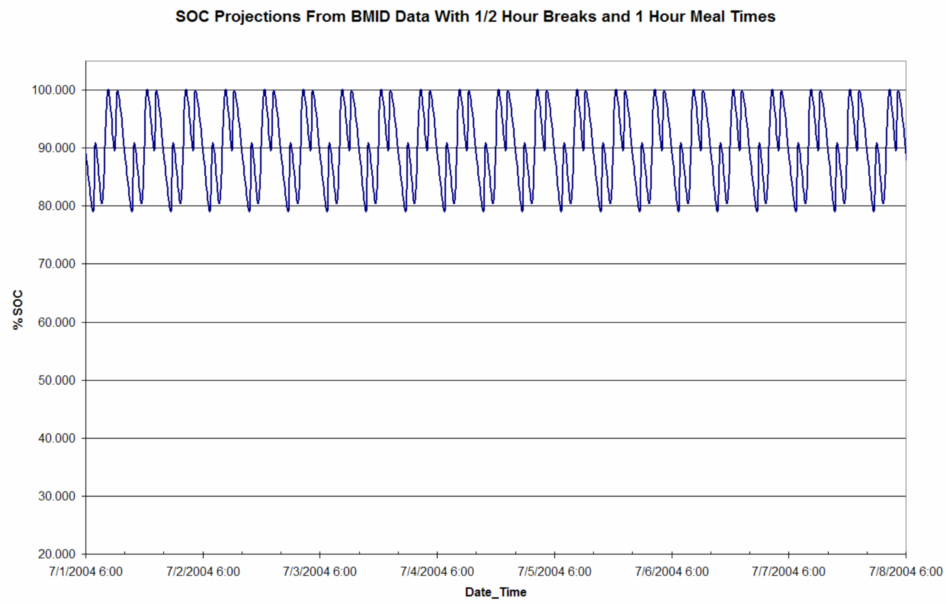

Figure 2-4
Daily SOC Projected Levels For Sustained 3-Shift Operations

For sustained operations 24 hours/day, 7 days/ week where charging is not allowed during shift changes, charging is required for ½ hour during breaks and 1 hour during meals. Reducing the break charging periods to 20 minutes does not allow the battery sufficient time to recharge resulting in daily decaying SOC levels until the battery becomes unusable at 20% SOC after 4 days as shown in Figure 2-5.

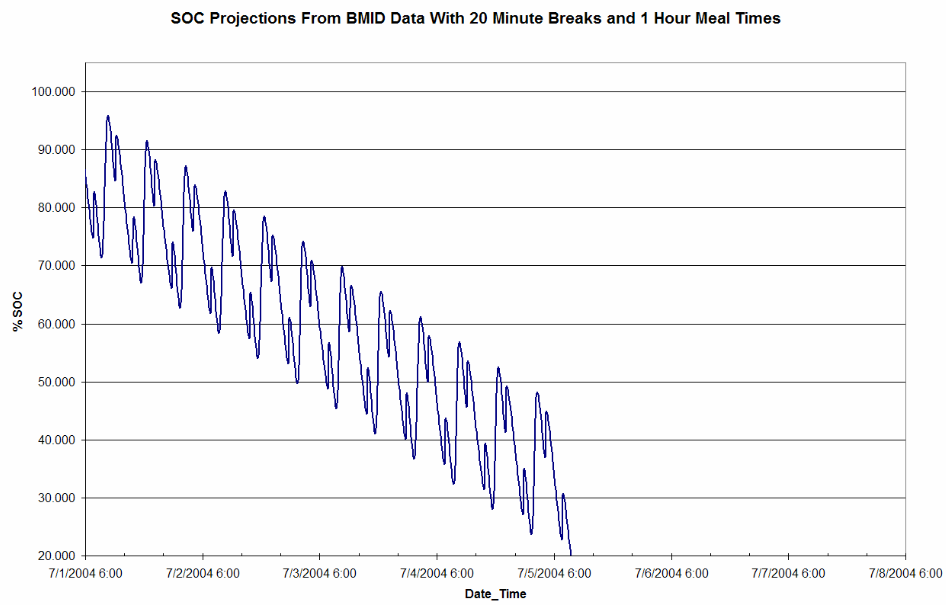

Figure 2-5
Daily SOC Projected Levels Where 3-Shift Operation Cannot Be Sustained

Since a small reduction in charge duration results in a decaying charge as illustrated by Figure 2-5, utilization of fast charging to avoid charging during peak revenue periods will not result in a sustainable mode of operation necessary for day in and day out operation.

Load Projections

Utilizing data from Hanford, in Table 2-8, the BMID number of charges is combined with the power demand and consumption data to project average charger demand and daily energy consumption associated with the charge cycle of a typical battery.

Table 2-8
Combined BMID and AC Data to estimate average power consumption

Charger Data		From:	9/17/2004 8:58:34		To:	9/23/2004 21:24:29			# of Days:	6.5
Charger	BMID	Watts, For Samples >		600	W.	Watt-Hrs, For Samples >			9.9978	Whr.
	Events	Count	Max	Avg	Min	Count	Max	Avg	Min	Accum
1	99	3188	34491	9204	751	3188	575	153	13	489039.2
2	45	1247	33833	6101	600	1248	564	102	10	126796.8
3	8	688	22741	6292	604	687	379	105	10	72066.3
4	19	416	22712	5577	1721	416	379	93	29	38667.2
Max	99	3188	34491	9204	1721	3188	575	153	29	489039
Average	43	1385	28444	***7871***	919	1385	474	113	15	181642
Min	8	416	22712	5577	600	416	379	93	10	38667
Total	171	5539	113777	27174	3676	5539	1896	453	61	***726570***
								Number of Batteries:		7
								KWh/Day/Battery:		15.969

Dividing the number of batteries into the total accumulated watt-hours results in a quotient that when divided by the number of days, results in the energy consumed per day per battery. This value is used in load projections associate with the different charge scenarios discussed in the next section.

3
CHARGING SCENARIOS

One of the major objectives of this study is to evaluate the impact of three charging scenarios with AC Forklifts on warehouse operations at Del Monte Foods. The scenarios are described in the following sections and daily load schedules are developed. The daily load schedules are used to project annual energy demand and consumption costs with 27 lifts in operating at the Warehouse.

Scenario 1 – Charging On Demand

The first scenario considers the affects of charging whenever possible. Typically, these charge times occur three times per shift; at each of the two breaks and the mid shift meal time. Consequently, on a typical day a battery received 9 charge cycles as detailed in Table 3-1.

Table 3-1
Daily loading schedule for a typical battery fast charging on demand

AC Monitor Data

15.969	kWh/bat/day charged
34.491	kW, Peak Sample Demand
22.329	kW, CP95 Sample Demand
7.871	kW, Average Sample Demand

Fast Charging - On Demand per lift Average Charges/Battery/Day: **9**

Shift	Hours		Lift	Break 1		2 hours between breaks		Dinner		2 hours between breaks		Break 2		4 hours between breaks	
	From	To		Break Start Time	Charge Duration Hrs.	Run Duration	Charge Energy, kWh	Break Start Time	Charge Duration Hrs.	Run Duration	Charge Energy, kWh	Break Start Time	Charge Duration Hrs.	Run Duration	Charge Energy, kWh
1st	6:00	14:00	A	8:00	0.23	1.77	1.774	10:00	0.23	1.77	1.774	12:00	0.23	3.77	1.774
2nd	14:00	22:00	A	16:00	0.23	1.77	1.774	18:00	0.23	1.77	1.774	20:00	0.23	3.77	1.774
3rd	22:00	6:00	A	0:00	0.23	1.77	1.774	2:00	0.23	1.77	1.774	4:00	0.23	3.77	1.774

Utilizing the assumptions in Table 2-1, a text file was developed providing demand and power consumption for each 30 second time interval over a 24 hour period. The resulting data was imported into PQView® allowing the power data to be plotted as illustrated in Figure 3-1.

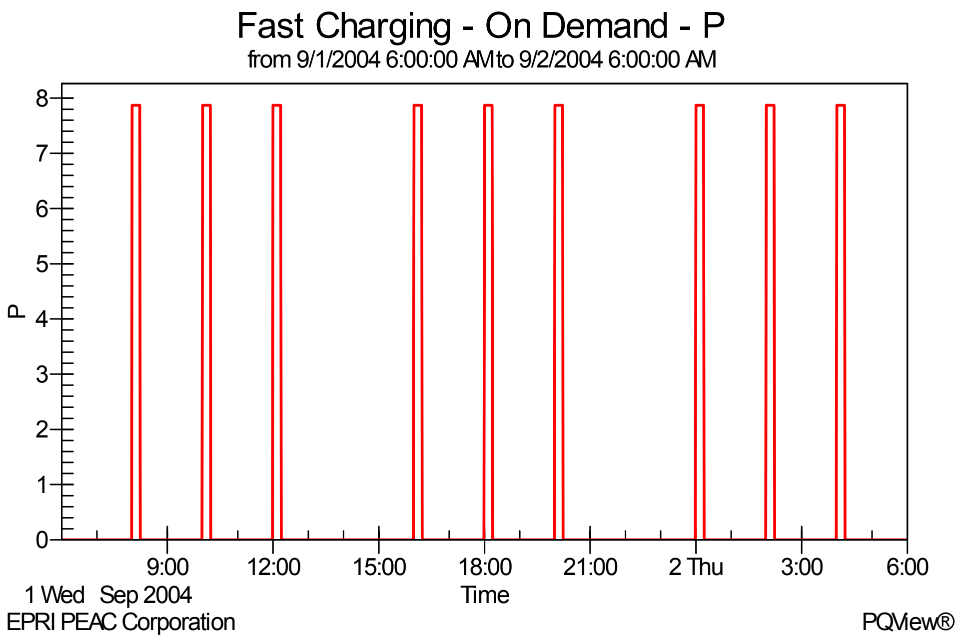

Figure 3-1
Average power (kW) charging trend based on the on-demand charging schedule

Note that there are three distinct pulses per shift. The center pulse in each of the three pulse groups represents mealtime charging while the remaining charging represents operator break times. No charging is performed during shift changes. Another approach to looking at the data is presented in Figure 3-2 where interval kwh is plotted referenced to the lefthand y-axis while accumulated kwh is plotted along the righthand 7-axis.

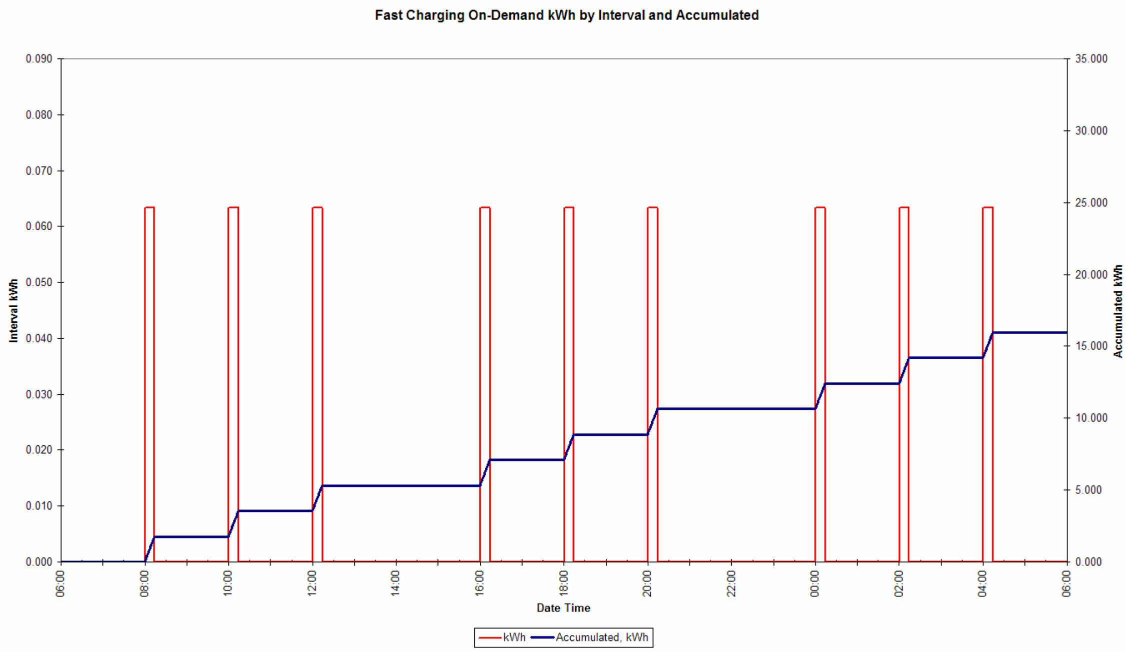

Figure 3-2
Interval Energy (kWh) and accumulation from the on-demand charging schedule

In Figure 3-2 it can be seen that the daily accumulated kWh reaches approximately 16 kWh matching the 15.969 kWh/day/battery value presented in Table 2-8. Applying the data supporting Table 3-1, Figure 3-1, and Figure 3-2, to annual warehouse billing data; results in annual billing costs for scenario 2 presented in Table 3-2.

Table 3-2
Projected energy costs for 27 warehouse lifts charging on demand

Read Date	Season PGE (S or W)	DMH (On or Off)	Shifts	**Customer Charges**	PGE Rates:	sumonpk_kwh	sumptpk_kwh	sumofpk_kwh	esales	**Energy Charges**	bl_demand	sumonpk_kw	sumptpk_kw	sumofpk_kw	**Demand Charges**	**Total Charges =Customer +Energy +Demand**
								Economic Stimulus Rate:	0.00000							
					Multipliers Summer:	0.20463	0.14966	0.13966			6.70	0.00	0.00	0.00		
					Multipliers Winter:		0.11660	0.10660			1.65	0.00	0.00	0.00		
11/13/03	W	Off	2	$0	E	13744	32085	47677	93506	$10,426	462	462	439	461	$762	$11,188
12/15/03	W	Off	2	$0	E	464	29765	37175	67403	$7,487	401	401	213	394	$661	$8,148
01/14/04	W	Off	2	$0	E	464	26165	33517	60146	$6,678	407	407	213	401	$671	$7,349
02/12/04	W	Off	2	$0	E	442	46961	42633	90037	$10,072	422	422	213	422	$696	$10,767
03/16/04	W	Off	2	$0	E	485	37929	39419	77832	$8,681	414	414	213	414	$682	$9,363
04/14/04	W	Off	2	$0	E	442	29681	27833	57957	$6,479	397	397	213	394	$654	$7,134
05/13/04	S	Off	2	$0	E	10442	32721	43513	86677	$13,111	461	461	444	461	$3,085	$16,196
06/15/04	S	Off	2	$0	E	26325	31849	49339	107512	$17,044	457	457	440	457	$3,059	$20,103
07/15/04	S	On	3	$0	E	24022	32069	83053	139144	$21,314	457	457	439	456	$3,059	$24,373
08/14/04	S	On	3	$0	E	30886	38724	110494	180104	$27,547	495	495	476	495	$3,313	$30,860
09/14/04	S	On	3	$0	E	27911	36661	121005	185577	$28,098	497	497	479	495	$3,327	$31,424
10/13/04	S	Off	2	$0	E	23882	30721	50553	105157	$16,545	491	491	491	461	$3,286	$19,832
			Total:	$0					Total:	$173,483				Total:	$23,254	$196,737.17

Projected Costs:	
With Electric Lifts	$196,737
Without Electric Lifts	$174,280
Difference	$22,457
Shifted On-Demand Difference	$5,003
Off-Peak Difference	$374

In the lower right hand corner of Table 3-2 the difference of $22,457 represents the annual cost of electrical energy consumptions to keep the 27 lifts appropriately charged.

Scenario 2 – Shifted Charging On Demand

The second scenario utilizes the same daily loading schedule as that applied to the first scenario for one lift while shifting the schedule by one hour for a second lift. While this does not impact the amount of energy used throughout the day on a per lift basis, it does impact peak demand levels when multiple lifts are charging simultaneously. While the typical battery still receives 9 charge cycles per day the same charge may be used for both batteries. This affectively doubles the number of charge cycles seen by the charger. Daily loading schedule for scenario 2 is presented in Table 3-3.

Table 3-3
Daily loading schedule for a typical battery shifted fast charging on demand

AC Monitor Data

15.969	kWh/bat/day charged
34.491	kW, Peak Sample Demand
22.329	kW, CP95 Sample Demand
7.871	kW, Average Sample Demand

Fast Charging - Shifted On Demand per 2 lifts — Average Charges/Battery/Day: **9**

Shift	Hours		Lift	Break 1		2 hours between breaks		Dinner		2 hours between breaks		Break 2		4 hours between breaks	
	From	To		Break Start Time	Charge Duration Hrs.	Run Duration	Charge Energy, kWh	Break Start Time	Charge Duration Hrs.	Run Duration	Charge Energy, kWh	Break Start Time	Charge Duration Hrs.	Run Duration	Charge Energy, kWh
1st	6:00	14:00	A	8:00	0.23	1.77	1.774	10:00	0.23	1.77	1.774	12:00	0.23	3.77	1.774
			B	9:00	0.23	1.77	1.774	11:00	0.23	1.77	1.774	13:00	0.23	3.77	1.774
2nd	14:00	22:00	A	16:00	0.23	1.77	1.774	18:00	0.23	1.77	1.774	20:00	0.23	3.77	1.774
			B	17:00	0.23	1.77	1.774	19:00	0.23	1.77	1.774	21:00	0.23	3.77	1.774
3rd	22:00	6:00	A	0:00	0.23	1.77	1.774	2:00	0.23	1.77	1.774	4:00	0.23	3.77	1.774
			B	1:00	0.23	1.77	1.774	3:00	0.23	1.77	1.774	5:00	0.23	3.77	1.774

Utilizing the assumptions in Table 3-3, a text file was developed providing demand and power consumption for each 30 second time interval over a 24 hour period. The resulting data was imported into PQView® allowing the power data to be plotted as illustrated in Figure 3-3.

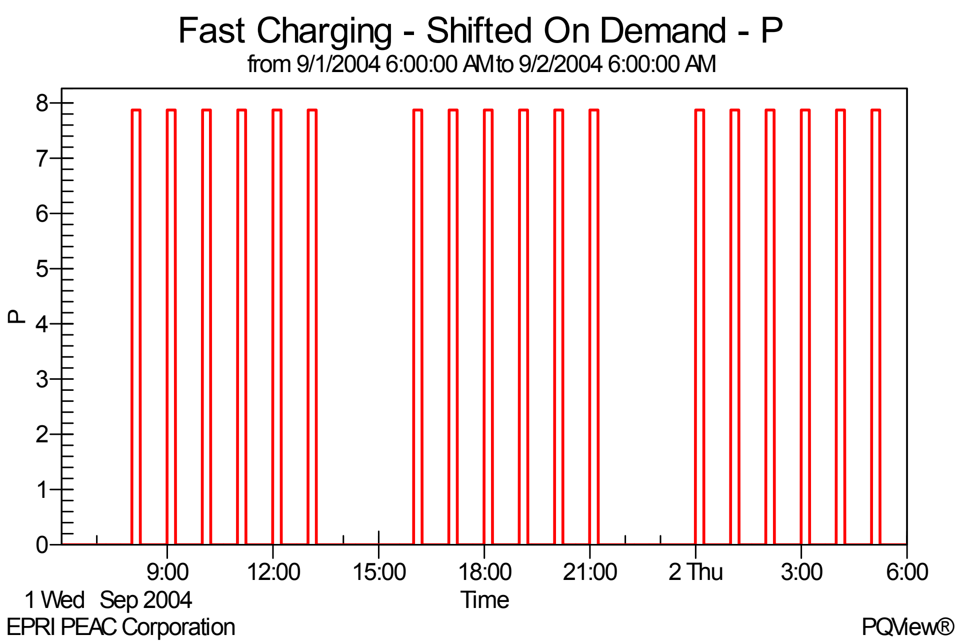

Figure 3-3
Average power (kW) charging trend based on shifted demand charging schedule

Note that there are six distinct pulses per shift. Every odd pulse represent charging of battery A while every even pulse represents charging of battery B. As previously presented in Figure 3-2 energy consumption for scenario 2 charging in presented in Figure 3-4.

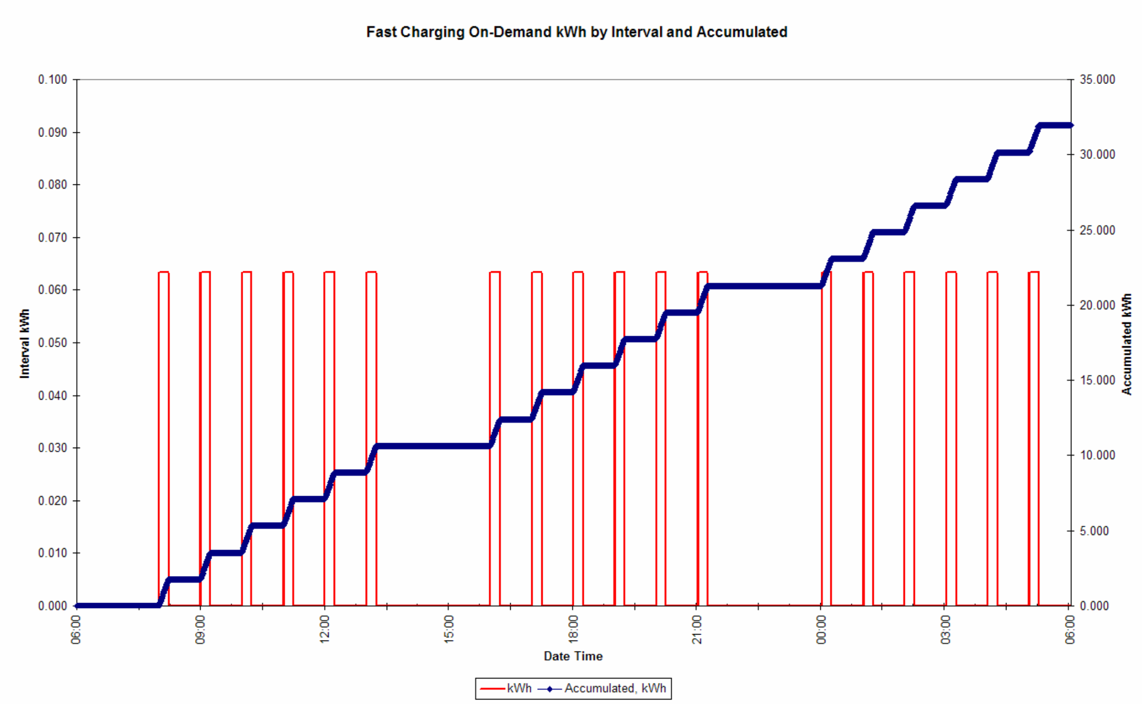

Figure 3-4
Interval Energy (kWh) and accumulation from the shifted on-demand charging schedule

In Figure 3-4 the daily-accumulated kWh reaches approximately almost 32 kWh. This is twice the energy consumption previously presented with the first scenario. This is due to two batteries charging in scenario 2 as compared with only one battery charging in scenario 1. Applying the data supporting Table 3-3, Figure 3-3, and Figure 3-4, to annual warehouse billing data; results in annual billing costs for scenario 2 presented in Table 3-2.

Table 3-4
Projected energy costs for 27 warehouse lifts charging on demand during shifted breaks

Read Date	Season PGE (S or W)	DMH (On or Off)	Shifts	Customer Charges	PGE Rates:	sumonpk_kwh	sumptpk_kwh	sumofpk_kwh	esales	Energy Charges	bl_demand	sumonpk_kw	sumptpk_kw	sumofpk_kw	Demand Charges	Total Charges =Customer +Energy +Demand
								Economic Stimulus Rate:	0.00000							
					Multipliers Summer:	0.20463	0.14966	0.13966			6.70	0.00	0.00	0.00		
					Multipliers Winter:		0.11660	0.10660			1.65	0.00	0.00	0.00		
11/13/03	W	Off	2	$0	E	13963	32082	47448	93492	$10,427	359	359	336	358	$593	$11,019
12/15/03	W	Off	2	$0	E	683	29762	36945	67389	$7,488	298	298	110	291	$492	$7,980
01/14/04	W	Off	2	$0	E	683	26162	33288	60132	$6,679	304	304	110	298	$502	$7,180
02/12/04	W	Off	2	$0	E	652	46958	42414	90024	$10,073	319	319	110	319	$527	$10,599
03/16/04	W	Off	2	$0	E	714	37925	39179	77818	$8,682	311	311	110	311	$513	$9,195
04/14/04	W	Off	2	$0	E	652	29678	27614	57944	$6,480	294	294	110	291	$485	$6,966
05/13/04	S	Off	2	$0	E	10652	32718	43294	86664	$13,123	358	358	341	358	$2,400	$15,523
06/15/04	S	Off	2	$0	E	26554	31845	49099	107498	$17,057	354	354	337	354	$2,373	$19,430
07/15/04	S	On	3	$0	E	24525	32060	82529	139114	$21,343	354	354	336	353	$2,373	$23,716
08/14/04	S	On	3	$0	E	31342	38717	110014	180074	$27,573	392	392	373	392	$2,628	$30,200
09/14/04	S	On	3	$0	E	28436	36652	120457	185545	$28,127	394	394	376	392	$2,641	$30,768
10/13/04	S	Off	2	$0	E	24092	30718	50334	105144	$16,557	388	388	388	358	$2,601	$19,158
			Total:	$0					Total:	$173,607				Total:	$18,128	$191,734.66
															Projected Costs:	
															With Electric Lifts	$191,735
															Without Electric Lifts	$174,280
															Difference	$17,454
															On Demand Difference	-$5,003
															Off-Peak Difference	-$4,629

In the lower right hand corner of Table 3-4, the difference of $17,454 represents the annual cost of electrical energy consumptions to keep the 27 lifts appropriately charged.

Scenario 3 – Charging Only Off Peak

At the end of section two of this report it was shown from projected data, that a forklift could operate without charging through the peak portion of the day where electrical energy rates are at a premium. The third scenario takes advantage of this capability by only allowing charging to occur during off peak periods. Consequently the number of available charge times is reduced from 9 to 7 charges per day. Since the forklift must do the same amount of work on a daily basis, energy consumption does not change. This means that during each charge more energy must be applied by increasing the charge time slightly. The daily loading schedule for scenario 3 is presented in Table 3-5.

Table 3-5
Daily loading schedule for a typical battery fast charging only during off peak periods

AC Monitor Data

15.969 kWh/bat/day charged
34.491 kW, Peak Sample Demand
22.329 kW, CP95 Sample Demand
7.871 kW, Average Sample Demand

Fast Charging - Off Peak per lift — Average Charges/Battery/Day: ***7***

Shift	Hours		Lift	Break 1		2 hours between breaks		Dinner		2 hours between breaks		Break 2		4 hours between breaks	
	From	To		Break Start Time	Charge Duration Hrs.	Run Duration	Charge Energy, kWh	Break Start Time	Charge Duration Hrs.	Run Duration	Charge Energy, kWh	Break Start Time	Charge Duration Hrs.	Run Duration	Charge Energy, kWh
1st	6:00	14:00	A	8:00	0.29	1.71	2.281	10:00	0.29	1.71	2.281	12:00	0.00	4.00	0.000
2nd	14:00	22:00	A	16:00	0.00	2.00	0.000	18:00	0.29	1.71	2.281	20:00	0.29	3.71	2.281
3rd	22:00	6:00	A	0:00	0.29	1.71	2.281	2:00	0.29	1.71	2.281	4:00	0.29	3.71	2.281

Utilizing the assumptions in Table 3-5, a text file was developed providing demand and power consumption for each 30 second time interval over a 24 hour period. The resulting data was imported into PQView® allowing the power data to be plotted as illustrated in Figure 3-5.

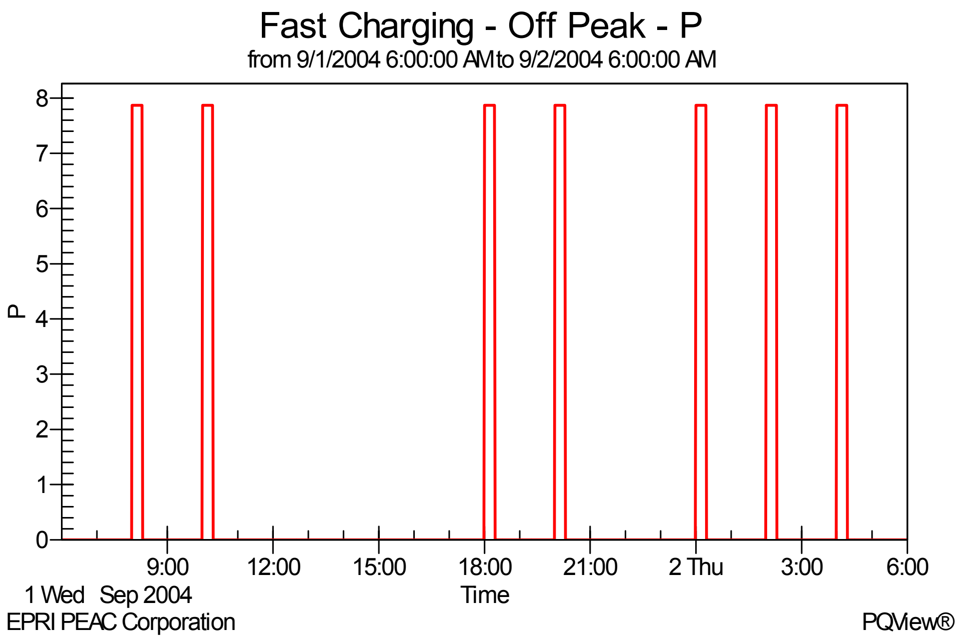

Figure 3-5
Average power (kW) charging trend based off peak charging schedule

For comparison purposes refer back to Figure 3-1. Note that the two pulses for 12:00 and 16:00 are missing. This is to purposely avoid charging between the peak hours of 12:00 and 18:00 each day. Interval and accumulated energy consumption for scenario 3 charging in presented in Figure 3-6.

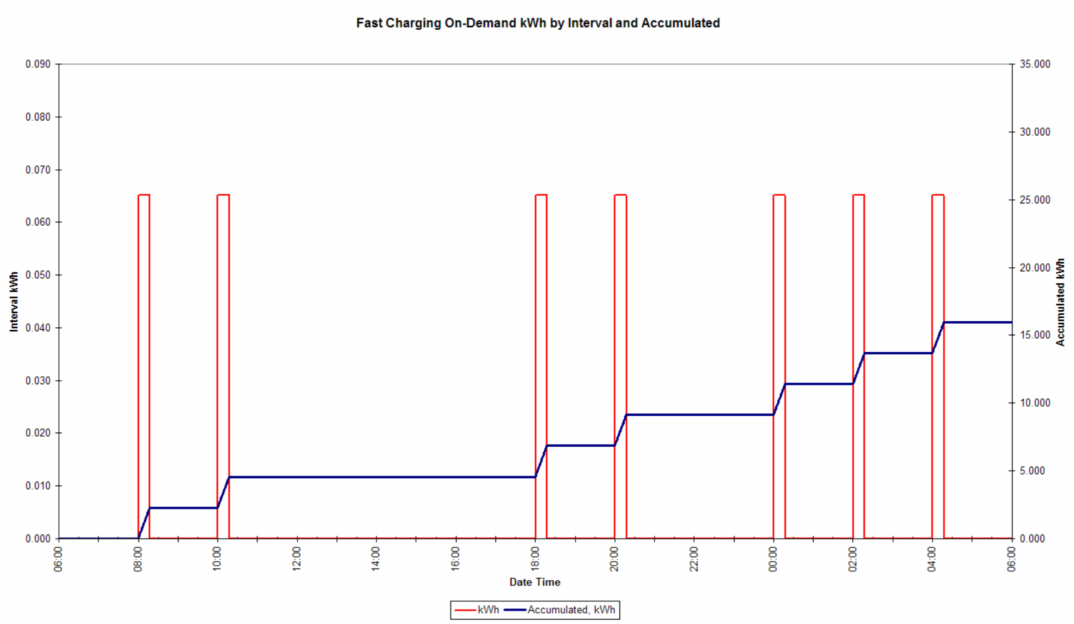

Figure 3-6
Interval Energy (kWh) and accumulation from the Off peak charging schedule

Similar to first scenario, in Figure 3-6 the daily accumulated kWh reaches approximately 16 kWh matching the 15.969 kWh/day/battery value previously presented in Table 2-8. Applying the data supporting Table 3-5, Figure 3-5, and Figure 3-6, to annual warehouse billing data; results in annual billing costs for scenario 3 presented in Table 3-6.

Table 3-6
Projected energy costs for 27 warehouse lifts charging off peak

Read Date	Season PGE (S or W)	DMH (On or Off)	Shifts	**Customer Charges**	PGE Rates:	sumonpk_kwh	sumptpk_kwh	Economic Stimulus Rate: sumofpk_kwh	0.00000 esales	**Energy Charges**	bl_demand	sumonpk_kw	sumptpk_kw	sumofpk_kw	**Demand Charges**	**Total Charges =Customer +Energy +Demand**
					Multipliers Summer:	0.20463	0.14966	0.13966			6.70	0.00	0.00	0.00		
					Multipliers Winter:		0.11660	0.10660			1.65	0.00	0.00	0.00		
11/13/03	W	Off	2	$0	E	13284	32020	48203	93507	$10,421	461	254	439	461	$760	$11,181
12/15/03	W	Off	2	$0	E	4	29700	37701	67405	$7,482	394	193	213	394	$649	$8,132
01/14/04	W	Off	2	$0	E	4	26100	34043	60147	$6,673	401	199	213	401	$661	$7,334
02/12/04	W	Off	2	$0	E	4	46899	43135	90038	$10,067	422	214	213	422	$696	$10,763
03/16/04	W	Off	2	$0	E	4	37861	39968	77834	$8,676	414	206	213	414	$682	$9,358
04/14/04	W	Off	2	$0	E	4	29619	28335	57958	$6,475	394	189	213	394	$649	$7,124
05/13/04	S	Off	2	$0	E	10004	32659	44015	86678	$13,082	461	253	444	461	$3,085	$16,167
06/15/04	S	Off	2	$0	E	25844	31781	49888	107514	$17,012	457	249	440	457	$3,059	$20,071
07/15/04	S	On	3	$0	E	22969	31919	84258	139146	$21,245	456	249	439	456	$3,052	$24,297
08/14/04	S	On	3	$0	E	29928	38588	111590	180106	$27,484	495	287	476	495	$3,313	$30,797
09/14/04	S	On	3	$0	E	26810	36504	122265	185579	$28,025	495	289	479	495	$3,313	$31,338
10/13/04	S	Off	2	$0	E	23444	30659	51055	105158	$16,516	491	283	491	461	$3,286	$19,803
			Total:	$0					Total:	$173,157				Total:	$23,206	$196,363.35
															Projected Costs:	
															With Electric Lifts	$196,363
															Without Electric Lifts	$174,280
															Difference	$22,083
															On-Demand Difference	-$374
															Shifted On-Demand Difference	$4,629

Scenario Comparisons

Referring back to Table 3-2, Table 3-4, and Table 3-6 difference calculations are made comparing the scenario results to the other two scenarios. A negative value indicates the projected energy costs currently being viewed are less then that of the scenario with the negative value. For example, the projected energy costs for shifted on demand charging previously presented in Table 3-4 indicates an on-demand difference of -$5,003 and off-peak difference of -$4,629. Since these values are both negative, scenario 2 provides the most savings in total energy costs. In Table 3-6 the On-Demand Difference is -$374 indicating that charging off-peak only results in $374 savings over charging on-demand. This shows that the rate structure applied to Warehouse billing does not result in significant energy cost differences between on-demand charging of-peak only charging. Additional evaluation of the rate structure serving the

Energy cost data from Table 3-2, Table 3-4, and Table 3-6 will be used support the economic analysis' of the three scenarios in the following section.

4
ECONOMIC ANALYSIS

Case studies were performed at the Del Monte Foods tomato-processing facility, located in Hanford, California, to determine the economics of three fast charging scenarios with AC Forklifts on warehouse operations. The economic studies considered capital costs for equipment, annual costs for maintenance and annual costs for electrical energy. Annual energy costs were based on facility past billing records and projections based on monitored data for the fast chargers being evaluated.

Warehouse Facility

The warehouse receives incoming finished product via pallet-trains from the production facility. Like most warehouse facilities the primary purposes of the warehouse is to store processed product for shipment and to facilitate product distribution. There are loading docks available for both shipments by truck or by freight train. As shown in Figure 4-1, a secondary purpose of the warehouse is to store unlabeled finish product called “bright's,” to be returned to the processing facility for future labeling. There are approximately 27 forklifts utilized at the warehouse facility.

Figure 4-1
Warehouse with “Brights” in storage

Operational Schedules

Operating schedules at the Del Monte Foods facility plant vary according to the two operating seasons: “on-season” and “off-season.” “On-season” occurs from July through mid October, with the reminder of the year being considered “off-season.” On-season the warehouse operates 24 hours a day across three shifts as shown in Table 4-1.

Table 4-1
On-season operating schedule for production and warehouse facilities

Shift	Hours		Start Times		
	From	To	Break 1	Dinner	Break 2
1st	6:00	14:00	8:00	10:00	12:00
2nd	14:00	22:00	16:00	18:00	20:00
3rd	22:00	6:00	0:00	2:00	4:00

During the “off-season” the warehouse typically operates for only the first two shifts. Exceptions do occur during off-season requiring three-shift operation. According to plant personnel, when considering plant downtime for holidays and maintenance, out of 365 days, three-shift operation represents 90 days and while two-shift operation occurs for 120 days. This leaves the remaining 155 days when forklifts are not in service.

The warehouse facility receives power at the 480V level from a 300 kVA transformer owned by the electrical service provider. The rate structure is based on a peak billing demand while tracking energy consumption based on time of day. Energy consumption rates very based on both time of day and season of the year. See Appendix A for rate schedule.

Battery Specifications

Previous electric forklift studies at Del Monte considered 48 V batteries applied to forklifts utilizing DC motors. In this study the batteries used were 80V batteries applied to AC motor driven forklifts. Table 4-2 provides battery specification data for the batteries associated with this study.

Table 4-2
Battery specification table

Battery:	80V Fast Charge
Manufacturer:	Exide
Model:	Loadhog
Rated Capacity	700 Ahr
Voltage:	80 VDC
Number of Cells:	40
Expected Life:	3 Years

Charger Specifications and Loads

Power monitoring was performed on the power supply to 4 fast chargers. For load projection studies individual charge periods were evaluated for peak demand (KW) and energy usage (KWh). The average demands were used and average energy usage was normalized to 30-minute intervals for load projections. Four PosiCharge Dual Vehicle Systems (DVS) were used for fast charging as specified in Table 4-3.

Table 4-3
Charger specification table

Charger Type:	Fast Charge
Manufacturer:	AeroVironment Inc.
MODEL:	DVS 300
DC Power Rating:	30 kW
Output Current In Single Charge Mode: (One vehicle charging)	500 ADC
Output Current in Dual Channel Mode: (Two vehicles charging)	250 ADC
Battery Voltage Range:	24 – 96 volt
Utility Requirements:	480 VAC, 60Hz, 50 Amps
Power Factor:	Power Factor .95
Efficiency:	Efficiency 90%
Dimensions:	60"h x 30"w x 20.5"d
Remote Access and Control:	RS232 Serial Port

Economic Analysis Of AC Lifts

Costs associated for the different charge scenarios for the Production and Warehouse facilities were annualized without regard for the value of money. For instance, if 10 conventional batteries costing $4,000 each are expected to have a service life of 6 years, the annualized cost of the 10 batteries is:

$4,000/battery x 10 batteries / 6 years = $6,666/year

Utilizing this approach first required a set of global assumptions as presented in Table 4-4.

Table 4-4
Global assumptions used for economic analysis

Number of Lifts…	65	Lifts
Production	38	Lifts
Warehouse	27	Lifts
Number of Tractors…	5	Tractors
On-season	5	Tractors
Off-season	3	Tractors
Annual Cost of Propane	$128,000	/Year
Annual Propane Maintenance Cost	$133,000	/Year
Electric Maintenance Costs…		
DC Lifts	$590	/Lift
AC Lifts	$295	/Lift
Battery Costs…		
80V Fast Charge	$7,500	/Battery
BIS	$300	/Battery
Battery Life…		
Fast Charge	3	Years
Charger Costs…		
80V Fast Charge	$11,500	/Charger
Charger Life	11	Years
Lift Life…		
AC Electric	10	
Lift Capacity	6000	Lbs
Annualized Lease Price of Lift…		
AC Electric	$4,493	/year

Plant personnel and interested vendors of the forklifts, batteries and chargers contributed the information used to populate Table 4-4. Annualized forklift leasing costs were determined utilizing a formula provided by Del Monte Foods' accounting group. The formula assumes a six-year lease with options to purchase at the end of the lease period.

The global assumptions were annualized and combined with annual energy costs to determine annual costs associated with the various charge scenarios. The resulting annualized cost comparison of each scenario is presented in Table 4-5.

Table 4-5
Annualized cost comparison of various charge scenarios

Use Senario	Charge On-Demand			Shifted Charge On-Demand			Charge Off-Peak		
	Lifts	**Bat.**	**Chrgrs.**	**Lifts**	**Bat.**	**Chrgrs.**	**Lifts**	**Bat.**	**Chrgrs.**
Equipment Quantities>>	27	27	14	27	27	7	27	27	14
Equipment Type>>	**Fast Charger 80V AC Lift**			**Fast Charger 80V AC Lift**			**Fast Charger 80V AC Lift**		
COSTS									
LIFT LEASE	$121,319			$121,319			$121,319		
BATTERY OWNERSHIP	$35,100			$35,100			$35,100		
CHARGER OWNERSHIP	$9,450			$4,725			$9,450		
MAINTENANCE	$7,965			$7,965			$7,965		
TOTAL NON-ENERGY COSTS:	$173,834			$169,109			$173,834		
ENERGY	$22,457			$17,454			$22,083		
- Consumption (KWH)	$12,195			$12,319			$11,869		
- Demand (KW)	$10,262			$5,136			$10,214		
TOTAL ANNUAL COSTS	**$196,290 ****			**$186,563 ****			**$195,917 ****		

Notes: * Does not include cost of battery handling equipment.
** Battery handling equipment not required, Cost of required extra lifts and associated equipment included.

Plant management has specified the need to fast charge only during meals and breaks. This type of scheduling results in high energy demands elevating energy costs. If 50% of the lift operator meals and breaks could be delayed by one hour, demands could be reduced resulting in energy demand savings of 22.3%. Under the Charge On-Demand scenario, one charger is required for every two lifts. Under the Shifted Charge On-Demand scenario, the same charger may be used to service 4 lifts. Therefore, only half as many chargers are required reducing capital costs by 2.7%.

As previously demonstrated by Figure 2-2, the ability to run for over 6 hours on a single charge allows for off-peak only charging. It was initially thought charging off-peak would significantly reduce energy costs. However, due to the flat load profile of the warehouse and since the warehouse rate structure only considers peak demand for the entire billing cycle, the savings of off-peak charging over on-demand charging was only 1.7%. Since the same number of chargers are required for off-peak charging as for on-demand charging there are no capital savings.

Comparison To Previous Work

The 2004 EPRI Report, *"Evaluation of Opportunities for Fast Charging Applications at Del Monte Foods* [4]," compared the economics of propane lifts to DC lifts utilizing conventional and fast charge batteries. Table 4-6 provides information extracted from Table 2-16 of the 2004 EPRI report next the data previously presented in Table 4-5.

4 *Evaluation of Opportunities for Fast Charging Applications at Del Monte Foods*, EPRI, Palo Alto, CA: 2004. 1002237.

Table 4-6
Annualized cost comparison of various charge scenarios presented in 2004 EPRI Report and new scenarios involving 80V AC lifts

	Data from 2004 Report			New Data		
Use Senario	Charge On-Demand	Staggered Charge On-Demand	Charge On-Demand From Substation	Charge On-Demand	Shifted Charge On-Demand	Charge Off-Peak
	Lifts / Bat. / Chrgrs.	Lifts / Bat. / Chrgrs.	Lifts / Bat. / Chrgrs.	Lifts / Bat. / Chrgrs.	Lifts / Bat. / Chrgrs.	Lifts / Bat. / Chrgrs.
Equipment Quantities>>	30 / 30 / 27	30 / 30 / 10	30 / 30 / 27	27 / 27 / 14	27 / 27 / 7	27 / 27 / 14
Equipment Type>>	Fast Charger DC Lift	Fast Charger DC Lift	Fast Charger DC Lift	Fast Charger 80V AC Lift	Fast Charger 80V AC Lift	Fast Charger 80V AC Lift
COSTS						
LIFT LEASE	$122,544	$122,544	$122,544	$121,319	$121,319	$121,319
BATTERY OWNERSHIP	$24,000	$24,000	$24,000	$35,100	$35,100	$35,100
CHARGER OWNERSHIP	$18,225	$6,750	$18,225	$9,450	$4,725	$9,450
MAINTENANCE	$17,700	$17,700	$17,700	$7,965	$7,965	$7,965
TOTAL NON-ENERGY COSTS:	$182,469	$170,994	$182,469	$173,834	$169,109	$173,834
ENERGY	$55,110	$42,138	$42,655	$22,457	$17,454	$22,083
- Propane						
- Consumption (KWH)	$38,147	$36,876	$26,748	$12,195	$12,319	$11,869
- Demand (KW)	$16,963	$5,262	$15,907	$10,262	$5,136	$10,214
TOTAL ANNUAL COSTS	**$237,579** **	**$213,132** **	**$225,124** **	**$196,290** **	**$186,563** **	**$195,917** **

Notes: * Does not include cost of battery handling equipment.
** Battery handling equipment not required, Cost of required extra lifts and associated equipment included.
*** Does not include cost of insurance associated with propane storage.

Considerably more monitoring data was available to support this report. Consequently, the projected energy consumption and demand costs associated with the 80V AC lifts represent more accurate values. If energy costs are ignored, the costs associated with the DC lifts are greater then that of the AC lifts. Maintenance costs provide the single most significant cost difference between AC and DC lifts as can be seen by comparing "Staggered Charge On-demand" from the DC lifts with the "Shifted Charge On-demand" from the AC lifts. For the economic studies evaluated in this report the cost of AC lift maintenance was assumed to be 50% of DC lift maintenance. This is considered to be a conservative estimate as at the time of this report there is not enough operating history with AC lifts to quantify at this time.

In parallel with this report a two page brief was developed comparing fast charging of 48V DC, 48V AC, and 80V AC forklifts. While offered as a separate deliverable the brief is provided in Appendix B. Del Monte suggested that a comparison be made between propane fueled internal combustion engine (ICE) motivated lifts, DC and AC lifts. This comparison is provided as a table in Appendix C.

5
CONCLUSION

DC technology using DC motors have dominated the electric forklift market. DC motor technology is mature requiring periodic maintenance associated with brush replacement. Recently, AC motor technology has been introduced into the electric forklift market. Still powered by DC batteries, blushless AC driven forklifts promise to provide better motive performance (faster acceleration) while eliminating maintenance costs associated brushes. Consequently, Del Monte Foods considers the efforts involved with the study as a learning experience. Based on their work with various chargers and batteries, Del Monte Foods is moving toward the use of higher voltage (80V) batteries and forklifts with AC motors.

Depending on plant load profiles, fast charging may or may not result demand reductions associated with conventional on-shift charging. This study shows on-peak and partial-peak demand reduction may be maximized using conventional charging only during off-peak times. For both the production and warehouse facilities, fast charging during breaks results in higher demands for each rate period then if conventional charging is used. On the other hand, fast charging during breaks results in lower energy usage (kWh) then conventional charging. Significant demand reduction may be achieved utilizing fast chargers if lift operators are required to stagger their break and dinner periods.

In three-shift operations, overall annual operational costs resulting in fast charging of batteries can be 12% to 23% less than conventional batteries. The rate type, number of shift operations, and type and quantity of batteries and chargers can all have significant impacts on energy costs.

Energy rate structures may not provide the best tool for shaping demand. In this study energy costs are shown to be less when fast charging is used for three-shift operations. This is mainly due to energy consumption (kWh) associated with conventional charging being greater during high rate periods relative to the lower energy consumption of the fast chargers. Actual demands associated with fast chargers may exceed those of conventional chargers however, fast charger demands are high for a shorter period of time then those demand associated conventional chargers.

Fast-charging on demand has a significant facility-wide impact on both peak demands and on-peak energy consumption resulting in elevated energy costs. On a regional level, fast-charging on demand will not support electrical infrastructure demand reduction or load leveling initiatives.

Future Considerations

Facility Considerations

To reduce energy costs at the warehouse the food processing plant should consider re-supplying power to the warehouse from the substation presently serving the production facility. This would allow the warehouse to receive the primary rate for power that the production facility is using. Spare circuit capacity is available at the substation to make this option feasible. Additional economic studies should be performed to determine the cost of infrastructure improvements associated with additional primary circuiting, transformer capacity and switchgear. If this option is exercised and electric chargers are used then consideration should be given to providing one transformer for the present warehouse loads and an additional transformer to serve the charger loads. The transformer serving the charger loads might be sized and used to support both the warehouse and production forklift chargers.

As with any electronic load applied to a transformer, if electronic loading exceeds 25% of the transformer rating then harmonic loading should be considered. These considerations should include:

- Load current harmonic spectrum measurement
- Transformer derating or K-Factor specification based on harmonic current spectrum
- Load power factor
- Affects of power factor correction capacitors.
- Voltage distortion due to harmonic loads

If fast chargers are used, placement of chargers may impact charger specifications. At Del Monte Foods, it is desirable to locate the chargers near the break and lunchroom facilities to reduce man-hours associated with personnel moving to and from the forklifts during break associated charging. Chargers may be located inside or outside while remaining near the break facilities. Locating chargers inside may seriously impact warehouse space, however; the charger specifications may be less stringent if chargers are only specified for internal use. If chargers are located external to the building, depending on what part of the country the chargers are located, the charger may need to be listed for rain tight usage. Extremely hot ambient conditions may adversely affect both charger and battery life while extremely cold conditions may adversely affect performance and battery life as well. Consequently charger specification and placement protocol will be site specific.

Future Study Considerations

Resulting from their investigations of various chargers and lifts, Del Monte Foods is planning to use electric forklifts that operate with an 80V battery system to power an AC motor driven forklift. The higher voltage batteries charge faster and operate cooler then their lower voltage (48V) fast charge counterparts. Besides having reduced maintenance cost (no brushes), the AC motor forklifts provide quicker response then traditional DC motor forklifts. Additionally, AC forklifts motive performance does not vary with battery SOC (between 80% and 20% SOC).

With conventional DC units, as the battery discharges the forklift performance becomes slower and more sluggish. The fast chargers being used to charge the higher voltage batteries also maintain battery state of charge data for each lift. This data may be used to determine forklift maintenance schedules as well as energy usage at the forklift level, plant level, regional level and corporate level. Monitoring AC power supplied to the fast chargers can allow comparison with battery state of charge data to support charger efficiency studies. The data may also be used to support business case analyses comparing AC and DC driven forklifts.

This report, along with other reports concerning various charging methods, typically rely on energy and demand data acquired at charger AC supply terminals without regard for data gathered on the charger load side to determine how much work is delivered thought the discharge cycle. This would require a DC voltage and current recorder on the forklift at all times. The data from the forklift recorder should be compared with monitored AC data associated with incoming charger power during battery charges. These same analyses should be performed on both a conventional charger/battery set and a fast charger/fast charger batter set. This way a true analysis may be made to determine the overall efficiency of fast charging versus conventional charging based on actual energy consumed by the forklift.

Data from the above-suggested studies may be used to support a feasibility study of flow-cell batteries. There have been recent developments and demonstrations utilizing flow batteries for large scale peak leveling. This existing technology uses a special “flow-cell” that produces voltage as electrolyte passes across the cell plates. The flowing electrolyte chemically changes as electrons are lost to the electric circuit the cell is providing power too. To reconstitute the electrolyte, the flow is reversed while voltage is applied to the cell. A forklift could be fitted with a flow-cell and two electrolyte reservoirs. One reservoir would be used to hold electron-rich electrolyte while the other reservoir would hold electron-depleted electrolyte. At the beginning of a shift or between breaks, the forklift is replenished with electron-rich electrolyte and the electron-depleted electrolyte would be returned to a plant wide electrolyte reservoir. The electrolyte reservoir could be recharged (enriched with electrons) continuously or controlled to charge more aggressively during off-peak hours providing demand load leveling for the plant and the power grid serving the facility. The electrolyte reservoir could also be recharged using an alternative energy source such as from photo-voltaics or from wind power. Since this approach has not been adapted to fork lifts, this is a new approach requiring a feasibility study to determine if it can technically be accomplished in a forklift and what energy consumption and demands might be expected. If the approach is feasible, the need for battery equalization may be eliminated and batteries may be refreshed faster then the current state-of-the-art fast chargers. Flow-cell batteries may provide the bridge to future fuel cells.

The 2002 EPRI report, "Power Quality Aspects of Ground Support Equipment[5]," provided a great overview of harmonic levels and power factors of a wide range of airport ground support equipment including both conventional and fast chargers. As more industrial and food processing facilities begin to realize the advantages associated with fast charging of electric forklift batteries there will be increased proliferation of this type equipment affecting the power grid. It is prudent to have an understanding of the various available fast-charging technologies. A study similar to that used for the previously mentioned EPRI study (5 above) should be

5 *Power Quality Aspects of Ground Support Equipment*, EPRI, Palo Alto, CA: 2004 1007294

performed focusing only on fast charging technologies. This study should look and SCR, IGBT and other technologies currently being used to consider power quality aspects typical of each technology. Some technologies may at first appear to be less expensive options, however power factor, high harmonic currents, poor efficiency and other impacts of a less expensive charger may result in higher implementation or long term operating costs. Such a study would help guide equipment buyers to which charger might be appropriate to maximize there economic advantage. Additionally, wise purchasing may also provide the most efficient and low harmonic solution affecting the area-wide power infrastructure.

A
PG&E RATE SCHEDULE A-10 AS APPLIED TO WAREHOUSE

Note:
At the time of this report rate-structure's were a matter of public record and made available at website: www.pge.com/tariffs.

The document presented on the following pages is subject to change at the authors' discretion and is being provided only as a reference to help in the understanding of energy cost calculations used in this report.

Pacific Gas and Electric Company		Revised	Cal. P.U.C. Sheet No. 19794-E
San Francisco, California	Cancelling	Revised	Cal. P.U.C. Sheet No. 19202-E

SCHEDULE A-10—MEDIUM GENERAL DEMAND-METERED SERVICE

APPLICABILITY: A customer selecting service on Schedule A-10 after August 15, 1992 must use at least 50,000 kWh per year. Schedule A-10 applies to single-phase and polyphase alternating-current service (for a description of these terms, see Section D of Rule 2). This schedule is not available to customers whose maximum demand exceeds 499 kW for three consecutive months, or to residential or agricultural service for which a residential or agricultural schedule is applicable, except for single-phase and polyphase service in common areas in a multifamily complex (see Common-Area (T)
Accounts section). (T)

Under Schedule A-10, there is a limit on the demand (the number of kilowatts (kW)) the customer may require from the PG&E system. If the customer's demand exceeds 499 kW for three consecutive months, the customer's account will be transferred to Schedule E-19 or E-20.

Customers who have received new hourly interval meters under the real-time metering program, funded by the California Energy Commission (CEC) pursuant to recently enacted California state legislation (Assembly Bill 1X 29), will pay the charges according to the terms and conditions in this schedule, and also the time-of-use (TOU) surcharges for Schedule A-10 specified under electric rate Schedule E-EPS, Section 2. These TOU surcharge rates will become effective for service rendered beginning on the customer's first regularly scheduled meter reading date which occurs after the new hourly interval metering system has been installed.

Customers who wish to voluntarily pay the TOU surcharges for Schedule A-10 specified under electric rate Schedule E-EPS, Section 2, must have an hourly interval meter. Those customers who wish to pay the TOU surcharge rates but who have not received hourly interval meters under the CEC-funded real-time metering program must pay PG&E for the cost of purchasing and installing an hourly interval meter, together with applicable Income Tax Component of Contribution (ITCC) charges and the cost to operate and maintain the interval meter. Customers who elect to receive service on this basis must sign an Interval Meter Installation Service Agreement Form (79-984).

The provisions of Schedule S—Standby Service Special Conditions 1 through 6 shall also apply to customers whose premises are regularly supplied in part (but not in whole) by electric energy from a nonutility source of supply. These customers will pay monthly reservation charges as specified under Section 1 of Schedule S in addition to all applicable Schedule A-10 charges. Customers who utilize solar generating facilities which are less than or equal to one megawatt to serve load and who do not sell power or make more than incidental export of power into PG&E's power grid and who have not elected service under Schedule E-NET, will be exempt from paying standby charges under this provision. Any customer under a time-of-use rate schedule using electric generation technology that meets the criteria as defined in Electric Rule 1 for Distributed Energy Resources is exempt from the otherwise applicable Standby Reservation Charges. Customers qualifying for this exemption shall be subject to the requirements outlined in the Standby Applicability section of this tariff.

TERRITORY: PG&E's entire service territory.

(Continued)

Advice Letter No. 2344-E	Issued by	Date Filed February 14, 2003
Decision No. 03-01-037	**Karen A. Tomcala**	Effective January 16, 2003
	Vice President	Resolution No.
47816	Regulatory Relations	

	Revised	*Cal. P.U.C. Sheet No.*	20545-E
Pacific Gas and Electric Company *Cancelling*	Revised	*Cal. P.U.C. Sheet No.*	19985-E
San Francisco, California			

SCHEDULE A-10—MEDIUM GENERAL DEMAND-METERED SERVICE
(Continued)

	Trans-mission	Distribu-tion	Public Purpose Programs	Genera-tion	Nuclear Decom-missioning	DWR Bond	FTA	Reliability Services	Total Rate
ENERGY CHARGE ($ per kWh)									
Transmission Voltage Level									
Summer	–	0.00275	0.00375	0.12598	0.00039	0.00513	0.01013	–	0.14813
Winter	–	0.00223	0.00375	0.10022	0.00039	0.00513	0.01013	–	0.12185
Primary Voltage Level									
Summer	–	0.00793	0.00368	0.13528	0.00038	0.00513	0.01013	–	0.16253
Winter	–	0.00647	0.00368	0.08445	0.00038	0.00513	0.01013	–	0.11024
Secondary Voltage Level									
Summer	–	0.01019	0.00380	0.12992	0.00040	0.00513	0.01013	–	0.15957
Winter	–	0.00832	0.00380	0.08389	0.00040	0.00513	0.01013	–	0.11167
DEMAND CHARGE (per kW of maximum demand per month)									
Transmission Voltage Level									
Summer	2.41 (I)	0.04	–	(1.65) (R)	–	–	–	1.15	1.95
Winter	2.41 (I)	0.00	–	(3.11) (R)	–	–	–	1.15	0.45
Primary Voltage Level									
Summer	2.41 (I)	3.29	–	(1.35) (R)	–	–	–	1.15	5.50
Winter	2.41 (I)	0.99	–	(2.90) (R)	–	–	–	1.15	1.65
Secondary Voltage Level									
Summer	2.41 (I)	4.72	–	(1.58) (R)	–	–	–	1.15	6.70
Winter	2.41 (I)	1.16	–	(3.07) (R)	–	–	–	1.15	1.65
CUSTOMER CHARGE per meter per day	–	2.46407	–	–	–	–	–	–	2.46407
TRANSMISSION REVENUE BALANCING ACCOUNT ADJUSTMENT RATE $ per kWh	(0.00230)	–	–	0.00230	–	–	–	–	0.00000

(Continued)

Advice Letter No. 2388-E-A	*Issued by*	*Date Filed* July 31, 2003
Decision No.	***Karen A. Tomcala***	*Effective* August 13, 2003
	Vice President	*Resolution No.*
48960	*Regulatory Relations*	

Pacific Gas and Electric Company
San Francisco, California

	Revised	*Cal. P.U.C. Sheet No.*	20546-E
Cancelling	Original	*Cal. P.U.C. Sheet No.*	19986-E

SCHEDULE A-10—TIME-OF-USE MEDIUM GENERAL DEMAND-METERED SERVICE
(Continued)

RATES:

	Trans-mission	Distribu-tion	Public Purpose Programs	Genera-tion	Nuclear Decom-missioning	FTA	Reliability Services	DWR Bond	Total Rate
Energy Charges (per kWh)									
Transmission Voltage Level									
Peak Period									
Summer	–	0.00275	0.00375	0.14982	0.00039	–	–	0.00513	0.16184
Winter	–	–	–	–	–	–	–	–	–
Part-Peak Period									
Summer	–	0.00275	0.00375	0.13764	0.00039	–	–	0.00513	0.14966
Winter	–	0.00223	0.00375	0.11528	0.00039	–	–	0.00513	0.12678
Off-Peak Period									
Summer	–	0.00275	0.00375	0.12764	0.00039	–	–	0.00513	0.13966
Winter	–	0.00223	0.00375	0.10528	0.00039	–	–	0.00513	0.11678
Primary Voltage Level									
Peak-Period									
Summer	–	0.00793	0.00368	0.19857	0.00038	–	–	0.00513	0.21569
Winter	–	–	–	–	–	–	–	–	–
Part-Peak-Period									
Summer	–	0.00793	0.00368	0.13254	0.00038	–	–	0.00513	0.14966
Winter	–	0.00647	0.00368	0.09951	0.00038	–	–	0.00513	0.11517
Off-Peak-Period									
Summer	–	0.00793	0.00368	0.12254	0.00038	–	–	0.00513	0.13966
Winter	–	0.00647	0.00368	0.08951	0.00038	–	–	0.00513	0.10517
Secondary Voltage Level									
Peak-Period									
Summer	–	0.01019	0.00380	0.18511	0.00040	–	–	0.00513	0.20463
Winter	–	–	–	–	–	–	–	–	–
Part-Peak-Period									
Summer	–	0.01019	0.00380	0.13014	0.00040	–	–	0.00513	0.14966
Winter	–	0.00832	0.00380	0.09895	0.00040	–	–	0.00513	0.11660
Off-Peak-Period									
Summer	–	0.01019	0.00380	0.12014	0.00040	–	–	0.00513	0.13966
Winter	–	0.00832	0.00380	0.08895	0.00040	–	–	0.00513	0.10660
DEMAND CHARGE (per kW Of maximum demand per Month)									
Transmission Voltage Level									
Summer	2.41 (I)	0.04	–	(1.65) (R)	–	–	1.15	–	1.95
Winter	2.41 (I)	0.00	–	(3.11) (R)	–	–	1.15	–	0.45
Primary Voltage Level									
Summer	2.41 (I)	3.29	–	(1.35) (R)	–	–	1.15	–	5.50
Winter	2.41 (I)	0.99	–	(2.90) (R)	–	–	1.15	–	1.65
Secondary Voltage Level									
Summer	2.41 (I)	4.72	–	(1.58) (R)	–	–	1.15	–	6.70
Winter	2.41 (I)	1.16	–	(3.07) (R)	–	–	1.15	–	1.65
CUSTOMER CHARGE (per meter per day)	–	2.46407	–	–	–	–	–	–	2.46407
OPTIONAL METER DATA ACCESS CHARGE per meter per day	–	0.98563	–	–	–	–	–	–	0.98563
TRANSMISSION REVENUE BALANCING ACCOUNT ADJUSTMENT RATE per kWh	(0.00230)	–	–	0.00230	–	–	–	–	0.00000

(Continued)

Advice Letter No.	2388-E-A	*Issued by*	*Date Filed* July 31, 2003
Decision No.		***Karen A. Tomcala***	*Effective* August 13, 2003
		Vice President	*Resolution No.*
48961		*Regulatory Relations*	

SCHEDULE A-10—MEDIUM GENERAL DEMAND-METERED SERVICE
(Continued)

RATES: (Cont'd.) Total rates include the applicable Energy Procurement Surcharges (EPS) listed in Schedule E-EPS. Generation is calculated residually based on the total rate less the sum of: Distribution, Transmission, Reliability Services, Public Purpose Program, Nuclear Decommissioning, Department of Water Resources ("DWR Bond") (where applicable), and FTA (where applicable). (T)

The above rate components apply to those customers eligible for the Rate Reduction Bond Credit. For those ineligible for the credit, the Generation component will be equal to the Generation component listed above plus the FTA component.

BASIS FOR DEMAND CHARGE: The customer will be billed for demand according to the customer's "maximum demand" each month. The number of kW used will be recorded over 15-minute intervals; the highest 15-minute average in the month will be the customer's maximum demand.

SPECIAL CASES: (1) If the customer's maximum demand has exceeded 400 kW for three consecutive months, 30-minute intervals will be used for averaging. The customer will be returned to 15-minute intervals when its maximum demand has dropped below 300 kW and remains there for 12 consecutive months; (2) If the customer's use of energy is intermittent or subject to violent fluctuations, a 5-minute or 15-minute interval may be used; and (3) If the customer uses welders, the demand charge will be subject to the minimum demand charges for those welders' ratings, as explained in Section J of Rule 2.

VOLTAGE DISCOUNTS: The customer may be eligible for a discount on the charges shown above if the customer takes delivery of electric energy at primary or transmission voltage.

The voltage discount, if any, will be applied to the Demand Charge.

Discounts are applied in any month as follows:

(1) $1.20 per kW of maximum demand in the summer season (as defined below), and $0.00 per kW of maximum demand in the winter season when service is delivered from a "single customer substation" or without transformation from PG&E's serving distribution system at one of the standard primary voltages specified in PG&E's Electric Rule 2, Section B.1.

(2) $4.75 per kW of maximum demand in the summer season (as defined below), and $1.20 per kW of maximum demand in the winter season when service is without transformation from PG&E's serving transmission system at one of the standard transmission voltages specified in PG&E's Electric Rule 2, Section B.1.

PG&E retains the right to change its line voltage at any time. Customers receiving voltage discounts will get reasonable notice of any impending change. They will then have the option of taking service at the new voltage (and making whatever changes in their systems are necessary) or taking service without a voltage discount through transformers supplied by PG&E.

(Continued)

Advice Letter No. 2364-E
Decision No. 02-12-082
48077

Issued by
Karen A. Tomcala
Vice President
Regulatory Relations

Date Filed April 1 2003
Effective April 1, 2003
Resolution No.

Pacific Gas and Electric Company
San Francisco, California

	Revised	Cal. P.U.C. Sheet No.	19988-E
Cancelling	Revised	Cal. P.U.C. Sheet No.	19795-E

SCHEDULE A-10—MEDIUM GENERAL DEMAND-METERED SERVICE
(Continued)

CONTRACT: For customers who use service for only part of the year, this schedule is available only on an annual contract.

SEASONS: The summer rate is applicable May 1 through October 31, and the winter rate is applicable November 1 through April 30. When billing includes use in both the summer and winter periods, demand and energy charges will be prorated based upon the number of days in each period.

COMMON-AREA ACCOUNTS: Common-area accounts that are separately metered by PG&E and which took electric service from PG&E on or prior to January 16, 2003, have a one-time opportunity to return to a residential rate schedule from April 1, 2004, to May 31, 2004, by notifying PG&E in writing.

In the event that the CPUC substantially reduces the three-cent surcharge or substantially amends any or all of PG&E's commercial or residential rate schedules, the Executive Council of Homeowners (ECHO) can direct PG&E to begin an optional second right-of-return period lasting 105 days. However, if this occurs prior to the April 1, 2004, to May 31, 2004, time period, the ECHO directed right of return period will be the only window for returning to a residential schedule.

Newly constructed common-areas that are separately metered by PG&E and which first took electric service from PG&E after January 16, 2003, have a one-time opportunity to transfer to a residential rate schedule during a two-month window that begins 14 months after taking service on a commercial rate schedule. This must be done by notifying PG&E in writing. These common-area accounts have an additional opportunity to return to a residential schedule in the event that ECHO directs PG&E to begin a second right-of-return period.

Only those common-area accounts taking service on Schedule E-8 prior to moving to this tariff may return to Schedule E-8.

Common-area accounts are those accounts that provide electric service to Common Use Areas as defined in Rule 1.

BILLING: A customer's bill is first calculated according to the total rates and conditions above. The following adjustments are made depending on the option applicable to the customer.

Bundled Service Customers receive supply and delivery services solely from PG&E. The customer's bill is based on the Total Rates and Conditions in this schedule, (T)
which includes the EPS provided in Schedule E-EPS (where applicable). (T)

(L)

(Continued)

SCHEDULE A-10—MEDIUM GENERAL DEMAND-METERED SERVICE
(Continued)

BILLING: (Cont'd.)

Direct Access Customers purchase energy from an energy service provider and continue receiving delivery services from PG&E. Direct Access bills are calculated as for Bundled Service Customers, reduced by the EPS listed in Section 2 of Schedule E-EPS, and the Direct Access credit set forth in Schedule EC. The resulting bill will include the Cost Responsibility Surcharge, applicable to Direct Access Customers. This charge and exemptions to this charge are further described in Schedule EC. (L) (T) (T) (L)

The DWR Bond charge is currently not applicable to Direct Access Customers. Pursuant to Decision 02-10-063 as modified by Decision 02-12-082, the DWR Bond charge may be collected from Direct Access Customers when a decision in Rulemaking 02-01-011 becomes final and unappealable. (N) (N)

Hourly Pricing Option: This option is suspended.

(D)

RATE REDUCTION BOND CREDIT:

Small commercial customers served on this schedule receive a 10 percent credit by way of a reduction to generation based on the total bill as calculated for Bundled Service Customers less the EPS revenues as provided in Schedule E-EPS. Only customers determined as eligible will receive the credit. (T) (T)

Additionally, customers eligible for the credit are obligated to pay a Fixed Transition Amount (FTA), also referred to as a Trust Transfer Amount (TTA), as described in Schedule E-RRB and defined in Preliminary Statement Part AS.

CARE DISCOUNT:

Facilities which meet the eligibility criteria in Rule 19.2 or 19.3 are eligible for a California Alternate Rates for Energy discount under Schedule E-CARE. Customers will continue to receive the CARE discount through PG&E regardless of energy service provider; and the CARE discount will be determined before any credit for Direct Access Service. (T) (T)

All Bundled Service Customers served on this Schedule shall pay the DWR Bond charge, except those customers who are eligible for CARE. For CARE customers, no portion of the rates shall be used to pay the DWR Bond Charge. Generation is calculated residually based on the total rate less the sum of: Transmission, Reliability Services, Distribution, Public Purpose Programs, Nuclear Decommissioning, and FTA (where applicable). (N) (N)

STANDBY APPLICABILITY:

DISTRIBUTED ENERGY RESOURCES EXEMPTION: Customers qualifying for an exemption from standby charges under Public Utilities (PU) Code Sections 353.1 and 353.3, as described above, must transfer to Schedule E-19, to receive this exemption until a real-time pricing program, as described in PU Code 353.3, is made available. Once available, customers qualifying for the standby charge exemption must participate in the real-time program referred to above. Qualification for and receipt of this distributed energy resources exemption does not exempt the customer from metering charges applicable to time-of-use (TOU) and real-time pricing, or exempt the customer from reasonable interconnection charges, non-bypassable charges as required in Preliminary Statement BB - *Competition Transition Charge Responsibility for All Customers and CTC Procurement*, or obligations determined by the Commission to result from participation in the purchase of power through the California Department of Water Resources, as provided in PU Code Section 353.7.

Pacific Gas and Electric Company
San Francisco, California

	Revised	Cal. P.U.C. Sheet No.	19990-E*
Cancelling	Revised	Cal. P.U.C. Sheet No.	19204, 19833-E

SCHEDULE A-10—MEDIUM GENERAL DEMAND-METERED SERVICE
(Continued)

DEFINITION OF TIME PERIODS: Customers who have received new hourly interval meters under the real-time metering program funded by CEC, or who have voluntarily arranged for the installation of such meters, will pay TOU surcharges as specified under electric rate Schedule E-EPS, Section 2. (L)

Times of the year and times of the day for the TOU surchage rates are defined as follows:

SUMMER	Period A (Service from May 1 through October 31):	
Peak:	12:00 noon. to 6:00 p.m.	Monday through Friday.
Partial-Peak	8:30 a.m. to 12:00 noon AND 6:00 p.m. to 9:30 p.m. Monday through Friday (except Holdays).	
Off- Peak:	9:30 p.m. to 8:30 a.m.	Monday through Friday
	All day	Saturday, Sunday, and holidays
WINTER	Period B (service from November 1 through April 30):	
Partial-Peak	8:30 a.m. to 9:30 p.m.	Monday through Friday (except holidays).
Off-Peak	9:30 p.m. to 8:30 a.m.	Monday through Friday (except holidays).
	All day	Saturday, Sunday, and holidays (L)

HOLIDAYS: "Holidays" for the purposes of this rate schedule are New Year's Day, President's Day, Memorial Day, Independence Day, Labor Day, Veterans Day, Thanksgiving Day, and Christmas Day. The dates will be those on which the holidays are legally observed.

CHANGE FROM SUMMER TO WINTER OR WINTER TO SUMER: When a billing month includes both summer and winter days, PG&E will calculate demand charges as follows. It will consider the applicable maximum demands for the summer and winter portions of the billing month separately, calculate a demand charge for each, and then apply the two according to the number of billing days each represents. NOTE: If the meter is read within one work day of the season changeover date (May 1 or November 1), PG&E will use only the rates and charges from the season having the greater number of days in the billing month. Workdays are Monday through Friday, inclusive.

DWR BOND CHARGE: The Department of Water Resources (DWR) Bond Charge was imposed by California Public Utilities Commission Decision 02-10-063, as modified by Decision 02-12-082, and is property of DWR for all purposes under California law. The Bond Charge applies to all retail bundled sales, excluding CARE and Medical Baseline sales. The DWR Bond Charge (where applicable) is included in customers' total billed amounts. Generation charges are reduced such that total charges do not increase as a result of the initial imposition of the bond charge. (T) (L) (L) (T) (T)

(Continued)

Advice Letter No. 2364-E	Issued by	Date Filed April 1, 2003
Decision No. 02-12-082	**Karen A. Tomcala**	Effective April 1, 2003
	Vice President	Resolution No.
48712	Regulatory Relations	

B

LIFT TRUCK COMPARISONS – DC DRIVES VERSUS AC DRIVES

fact sheet

Lift Truck Comparisons—DC Drives Versus AC Drives

BACKGROUND

In 2004, EPRI published the document "Evaluation of Opportunities for Fast Charging Application at Del Monte Foods," Palo Alto, CA: 1002237. This document considered the economic impacts of forklift operations utilizing propane, conventionally charged batteries, and fast charged batteries. This analysis considered both warehouse and production operations and the impacts of rate structures for secondary and primary power delivery.

Resulting from their investigations of various chargers and lifts, Del Monte Foods is proceeding with plans to use AC motor-driven lift trucks powered by fast charged batteries. At one facility the AC lifts operate from 48V batteries while another facility utilizes lifts that operate from an 80V battery system. The new fast-charger being used by Del Monte Foods is capable of charging both the 48V and 80V fast-charge battery systems associated with this new equipment. With these new 48V and 80V AC forklifts available alongside new DC units, EPRI took advantage of the opportunity for comparison studies of these new technologies.

APPROACH

EPRI investigators developed comparative data from equipment vendor interviews, forklift operator interviews, and field measurements. Equipment vendor interviews provided insight into the comparative capital and maintenance costs associated with the different forklifts, battery configurations, and fast-charging equipment. Forklift operator interviews provided an understanding of forklift performance issues. Information from the forklift operators was compared with monitored data obtained from the chargers and from independent revenue meters placed on the AC supply to the fast-chargers.

RESULTS

Interview and monitored data were gathered for 3 different forklift systems. Economic analysis compared annual operational costs. Results are summarized in the comparison table on Page 2.

CONTACT INFORMATION For more information, contact the EPRI Customer Assistance Center (EPRI CAC) at 800.313.3774 or askepri@epri.com

TECHNICAL CONTACT A. Rogers, 650.855.2101, arogers@epri.com

Issue	48V DC Forklift	48V AC Forklift	80V AC Forklift
Performance	Lifting and motive performance degradation is noticeable when battery state of charge (SOC) is between 30% and 20%. Speed is regulated (Note 2).	Lifting and motive performance is constant regardless of battery SOC above 20% (Note 1). Speed is regulated (Note 2).	Lifting and motive performance is constant regardless of battery SOC above 20% (Note 1). Speed is regulated (Note 2).
Runtime	Under same work load and operating conditions the AC lift will operate longer than the DC lift. This is due to energy savings associated with AC lift regenerative breaking and lack of hydraulic systems.	Under same work load and operating conditions the AC lift will operate longer than the DC lift. This is due to energy savings associated with AC lift regenerative breaking and lack of hydraulic systems.	Under same work load and operating conditions the AC lift will operate longer than the DC lift. This is due to energy savings associated with AC lift regenerative breaking and lack of hydraulic systems.
Noise	While the operational sounds from the AC and DC lifts differ, both are sufficiently quiet to be ignored.	While the operational sounds from the AC and DC lifts differ, both are sufficiently quiet to be ignored.	While the operational sounds from the AC and DC lifts differ, both are sufficiently quiet to be ignored.
Environmental	Brushes are inherent in DC motors to couple electrical energy into the motor rotor. Brush wear produces dust that can be released into the environment on a daily basis or during brush replacement.	Brushless AC motors do not produce dust that might be released into the environment.	Brushless AC motors do not produce dust that might be released into the environment.
Reliability	Very reliable assuming maintenance issues are appropriately addressed.	Relatively new technology, is expected to be more reliable then DC lifts due to lower maintenance issues. Drive reliability is expected to be very high. However, more operational history is needed to support this assessment.	Relatively new technology, is expected to be more reliable then DC lifts due to lower maintenance issues. Drive reliability is expected to be very high. However, more operational history is needed to support this assessment.
Maintenance	Brush replacement and cleaning of dust residue is required for DC forklifts. Break replacement is required more often for DC lifts.	AC lifts are brushless and require less break maintenance than DC lifts due to regenerative breaking capability.	AC lifts are brushless and require less break maintenance than DC lifts due to regenerative breaking capability.
Equipment Cost	100 % (Note 3)	Estimated to be 104% the cost of a DC forklift.	Estimated to be 110% the cost of a DC forklift.
Maintenance Cost	100 % (Note 3)	Estimated to be 34% of DC forklift based on savings associated with longer break life and not having to deal with brush replacement issues.	Estimated to be 34% of DC forklift based on savings associated with longer break life and not having to deal with brush replacement issues.
Battery Life	No appreciable difference with same voltage system.	No appreciable difference with same voltage system.	110% that of 48V system due to cooler charge and discharge cycles. More operational history is needed to support this assessment.
Battery Recharge Rate	No appreciable difference with same voltage system.	No appreciable difference with same voltage system.	Faster recharge rate for higher voltage battery having the same run time as 48V system. Additional studies required to quantify this assessment.
Charger Costs	No cost difference. Same charger may be used for all listed voltage levels.	No cost difference. Same charger may be used for all listed voltage levels.	No cost difference. Same charger may be used for all listed voltage levels.
Energy Consumption	No appreciable difference with same voltage system.	No appreciable difference with same voltage system.	Comparison data not available. Slightly higher consumption is expected due to larger physical size and less efficient tires.
Economics	1.00, (Note 4)	0.92	1.11
Features			
– Running Motor	DC	AC	AC
– Power Steering	Hydraulic	AC	AC
– Lifting Motor	Hydraulic	AC	AC
– Breaking	Conventional Pad and Drum	Regenerative with Conventional Assist	Regenerative with Conventional Assist
– Empty Weight	8086 Lbs	8086 Lbs	8086 Lbs
– Battery Weight	3396 Lbs	3396 Lbs	4600 Lbs
– Lift Capacity	6000 lbs	6000 lbs	6000 lbs
– Tires	Cushion Tire	Cushion Tire	Solid Pneumatic Tires for Outside Use

Notes:
1. No testing was performed below 20% SOW to avoid permanent battery damage.
2. Speed is electronically regulated on all lifts for safety.
3. Comparison Basis
4. Economics considers annual equipment and maintenance costs. Values are based on per unit cost of a DC lift. For example: If it costs $1000 per year to lease and maintain a DC lift, a comparable 48V AC lift would cost $920 per year and a comparable 80V AC lift would cost $1100 per year.

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C
LIFT TRUCK COMPARISONS – ICE, DC AND AC DRIVES

Category	Propane Forklift	Fast Charged 48V DC Forklift	Fast Charged 48V AC Forklift
Performance	Performance is independent of fuel level.	Lifting and motive performance degradation is noticeable when battery state of charge (SOC) is between 30% and 20%. Speed is regulated (Note 2). Reduced lifting speeds during low SOC levels negatively impacts productivity and puts more mechanical stress on lifting system.	Lifting and motive performance is constant regardless of battery SOC above 20% (Note 1). Speed is regulated (Note 2).
Runtime	Dependent on workload and tank capacity. Typically, can operate a full shift without refueling.	Dependent on workload and battery capacity. Recharging typically required 2 times per shift.	Dependent on workload and battery capacity. Recharging typically required 2 times per shift.
Battery Recharge Rate/Propane Refueling Time	Typically 20-30 minutes is required for round trip including refueling and travel time. This off-station time negatively impacts productive capacity for shipping.	Typically 15 - 30 minutes per charge. With strategic placement of charging stations near break facilities, idle capacity may be used for charging during breaks.	Typically 15 - 30 minutes per charge. With strategic placement of charging stations near break facilities, idle capacity may be used for charging during breaks.
Noise	While not deafening, noise from internal combustion engine is significantly greater then the electric counterparts.	While the operational sounds from the AC and DC lifts differ, both are sufficiently quiet to be neglected.	While the operational sounds from the AC and DC lifts differ, both are sufficiently quiet to be neglected.
Environmental	Exhaust from propane forklifts contributes to poor environmental air quality. Exhaust can blow dust particulates into eyes. Exhaust and engine heat contribute to elevated ambient temperatures.	Brushes are inherent in DC motors to couple electrical energy into the motor rotor. Brush wear produces dust that can be released into the environment on a daily basis or during brush replacement.	Brushless AC motors do not produce dust that might be released into the environment.
Reliability	Reliable assuming maintenance issues are appropriately addressed.	Very reliable assuming maintenance issues are appropriately addressed.	Relatively new technology, is expected to be more reliable then DC lifts due to lower maintenance issues. Drive reliability is expected to be very high however more operational history is needed to support this assessment.
Maintenance	brake replacement is required as often as DC lifts. Engine overhaul is an expected maintenance expense unless absorbed by lease cost.	Brush replacement and cleaning of dust residue is required for DC Forklifts. Brake replacement is required more often for DC lifts then for AC lifts. Lifting system mechanical stresses during low SOC levels increase maintenance requirements and associated costs.	AC lifts are brushless and require less brake maintenance then DC lifts due to regenerative braking capability.
Maintenance Cost	1.00, (Note 3)	0.68	0.23
Equipment Cost	1.00, (Note 4)	1.61	1.65
Fuel Storage Costs	Added insurance costs associated with on-site fuel storage. Associate equipment costs not considered in economics below.	Not Applicable	Not Applicable
Energy Consumption	1.00, (Note 3)	0.61	0.61
Economics	1.00, (Note 5)	0.79	0.77
Features - **Running Motor** - **Power Steering** - **Lifting Motor** - **Braking** - **Empty Weight** - **Battery Weight** - **Lift Capacity** - **Tires**	 Propane fueled I.C. Engine Hydraulic Hydraulic Conventional Pad and Drum 8086 Lbs 3396 Lbs 6000 lbs Cushion Tire	 DC Hydraulic Hydraulic Conventional Pad and Drum 8086 Lbs 3396 Lbs 6000 lbs Cushion Tire	 AC AC AC Regenerative with Conventional Assist 8086 Lbs 3396 Lbs 6000 lbs Cushion Tire

Notes:

1 No testing was performed below 20% SOW to avoid permanent battery damage.
2 Speed is electronically regulated on all lifts for safety.
3 Comparison Basis, values are based on per unit cost of a propane lift. For example: If it costs $1000 per year to maintain a propane lift, a comparable 48V DC lift would cost $680 per year and a comparable 48V AC lift would cost $230 per year.
4 Annualized cost of fork lifts, batteries, and battery chargers. Values are based on per unit cost of a propane lift.
5 Economics considers annual equipment, maintenance, labor and energy costs. Values are based on per unit cost of a propane lift.

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