1 Summary

Customer:	Customer	**Audit Date:**	4/20/04
Address:	1 Main Street	**Peak kW:**	463 kW
City, State:	Anytown, RI	**2003 ISO DR kW:**	0 kW
Industry:	Beer distribution warehouse	**Potential kW:**	159 kW

Next Steps:

1. Consider signing-up for Narragansett Electric and ISO-NE's demand response programs. Customer has a moderate amount of load shed and shift potential.
2. Develop a demand response plan to activate and provide timely demand response when called by Narragansett Electric of ISO New England.
3. Carefully consider the potential benefits and consequences of pre-cooling the CEW warehouse. If done carefully, this can be a very effective load shift.
4. Request technical assistance studies for:

- High bay lighting retrofit and occupancy/dimming controls,
- Conversion to hot gas defrost on evaporators, and
- Distribution modifications for 480V battery charging.

This report has been provided to assist Customer in understanding their electrical usage and potential for demand response. Fundamentally, demand response is a concerted effort to temporarily reduce electrical consumption during specific times of need. Some uses of electricity are discretionary, or easily done without, while others are mission-critical. When economic incentives are available for demand response, or when it is requested to mitigate grid instability, customers often find most electrical usage falls somewhere in between.

Through a detailed review of energy consumption data and operational characteristics, this report is intended to provide insight into potential demand reduction opportunities at Customer.

2 Load Characteristics

In this section, we detail an examination of the electrical load at Customer. **Summary Statistics** presents some key energy and demand tabulations, both annually and focusing on the summer season from June through September. In **Characteristics of Load**, we report a high-level overview of facility operations, electrical end-use equipment, and operational patterns. **Load Duration Curve Analysis** is an analytical examination of the hours during which the facility draws peak electrical demand and inference of the loads that comprise these peaks.

2.1 Summary Statistics

Annual Data for 2003

Period Analyzed:	**From:**	01/01/03	**To:**	12/31/03

	On-Peak	Off-Peak	%On-Peak	Total
Energy (kWh):	807,448	881,171	48%	1,688,619

	On-Peak	Off-Peak	Weekday	Total
Avg. Demand (kW):	238	164	216	193
Max Demand (kW):	463	**Date/time:**	Fri, Jun 27, 2003 at 4:30 PM	
Load Factor:	51%	41%		

Peak Period Data (June-September 2003)

Period Analyzed:	**From:**	06/01/03	**To:**	09/30/03

	On-Peak	Off-Peak	%On-Peak	Total
Energy (kWh):	279,578	285,553	49%	565,131

	On-Peak	Off-Peak	Weekday	Total
Avg. Demand (kW):	247	159	217	193
Max Demand (kW):	463	**Date/time:**	Fri, Jun 27, 2003 at 4:30 PM	
Load Factor:	53%	39%		

The Load Factor parameter is a useful indicator of how often electrical demand is high across an extended period. By definition, it is the ratio of the average load over a designated period of time to the peak load occurring during that period. A low load factor implies a spiky load, and high load factor indicates the load is more consistent or 'flatter' across the period. The on-peak summer load factor of 53% at Customer suggests a somewhat inconsistent and spiky load shape during a key period of interest: summer weekdays from 8am to 9pm.

For Customer, the annual peak occurs during the summer months. Slightly higher demand and load factor values for summer versus annual tabulations suggest a temperature influenced increase, though there may also be operational differences in the summer. It is interesting to note that the average weekday demand is just 1 kW higher in the summertime than the annual average.

2.2 Characteristics of Load

Customer is a refrigerated warehouse that inherently operates around the clock. Operations are focused generally between 8:00am and 7:00pm, Monday through Friday. A minimal crew is present for Saturday deliveries. From May through September, Saturday operations are increased with draft beer deliveries from 7am to noon.

Major End Uses	Estimated Connected kW	Hours of Operation
Refrigeration	516 kW	24/7
Electric Defrost	205 kW	Varies
Lighting	92 kW	6AM-8PM, M-F
Office HVAC	87 kW	5AM-6PM, M-F
Battery Chargers	33 kW	24/7
Misc. Office Equipment	24 kW	8AM-5PM, M-F
Exhaust Fans	9 kW	Varies
TOTAL	**966 kW**	

This 114,000 ft^2 Customer facility ____ is in Rhode Island. The major functional spaces are:

- A 57,000 ft^2 Controlled Environment Warehouse (CEW) for packaged products;
- A 5,000 ft^2 cooler for barrels, maintained at 34-36 °F year-round;
- An 18,000 ft^2 "drive-thru" for side loader trucks; and
- Approximately 16,000 ft^2 of office space.

Beer arriving at this facility is produced in __________________________ The time and even day of shipment arrivals is variable and unpredictable. The temperature set point for the barrel cooler is strictly controlled year-round, while the CEW warehouse varies monthly (from 40 °F to 69 °F in 2004) according to company-defined set points. The drive-thru is conditioned in the summer to serve as a buffer between outdoor temperatures and the CEW and cooler. When outdoor temperature and humidity permits, free cooling (pure ventilation) is employed in the drive-thru and CEW spaces.

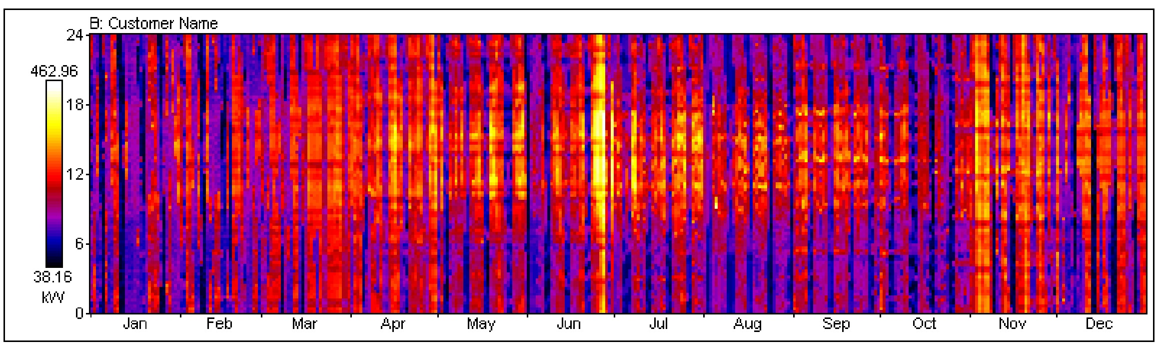

Figure 1: 2003 Energy Print™ for Customer

The Energy Print™ above is a concise yet detailed representation of every 15-minute demand reading throughout 2003 at Customer. The horizontal axis contains all 365 days of the year, while the vertical axis is hour of day (0 through 24). The location of a point on this Energy Print represents the time of the reading, while the color as depicted by the legend on the left indicates the demand at that time.

The Energy Print above possesses less structure than most. It is indicative of a five day-per-week operation (vertical stripes) with little time-of-day structure (horizontal banding). We see evidence of a seasonal cooling component, however the increased usage in November suggests other influences, which will be discussed later.

2.3 Load Duration Curve Analysis

A load duration curve is another term for a demand frequency distribution graph. Such curves express the relationship between time and demand, showing the percent of time that the facility demand is at a certain demand level. Amongst other insights, a load duration curve is a tool for identifying instances where just a few culprit hours are associated with high demand. Infrequent yet anomalous high demands are characterized by a steep (approaching vertical) slope in the 90%-100% percentiles of time. The load duration curve for Customer is presented below in Figure 2.

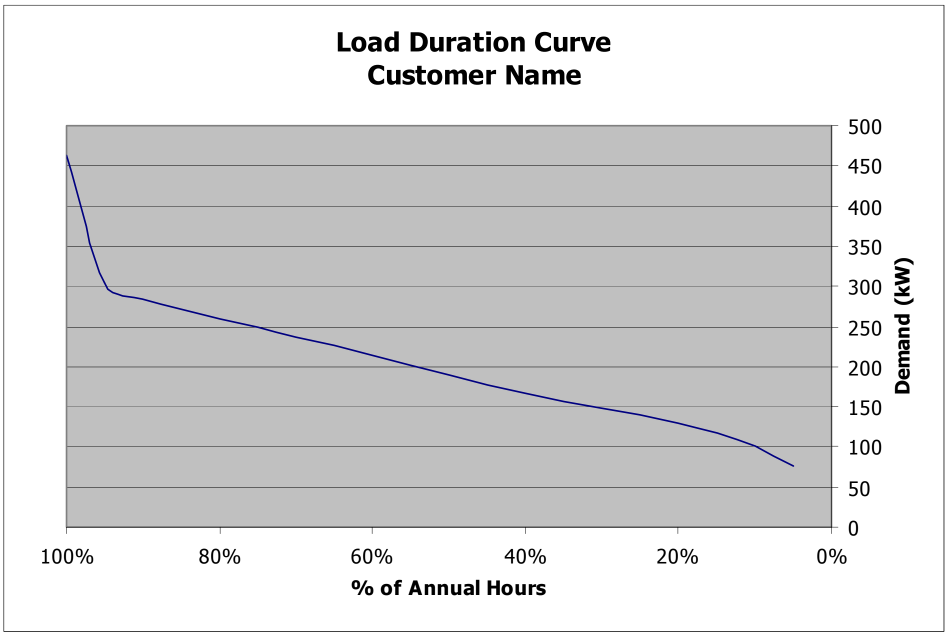

Figure 2: Load Duration Curve

The moderate slope of the majority of the load duration curve for Customer is characteristic of fairly diverse operation. In of itself, the 150 kW "dog leg" in the top 5% of annual hours means that relatively few hours are responsible for a much of the peak demand. If Customer was interested in proactively limiting its peak demand, this suggests a reasonable savings potential. As the load duration curve does not characterize time-of-day or electrical end-use, it provides little insight to the potential for demand response.

However, based upon discussion with the warehouse manager and review of interval load data, much of this peak occurs at the end of June. While refrigeration usage for this warehouse is indeed a function of outdoor temperature, warehouse throughput (thermal mass of product stored and frequency of shipments, e.g. door openings) is almost certainly a greater influence for this increased usage. The remainder of the load duration curve slopes steadily down to a 5^{th} percentile load of 77 kW, suggesting a wide and diverse usage profile. This low base usage (about 15% of the connected refrigeration load) suggests that there are periods of very low refrigeration use throughout the year. In fact, this bottom 5% of annual hours is likely comprised of winter times when Customer are able to utilize outdoor ventilation for the CEW warehouse.

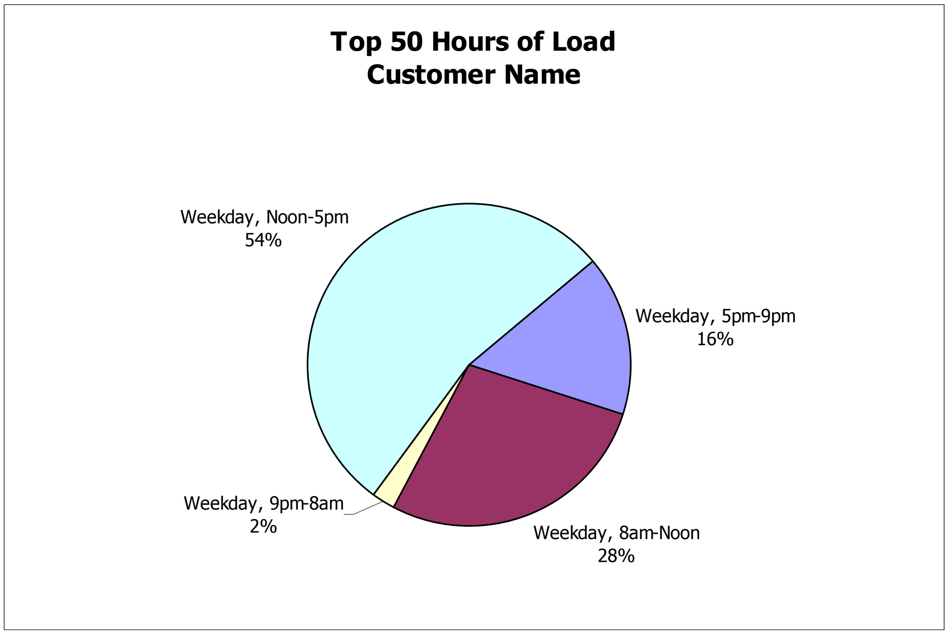

Figure 3: Top 50 Hours of Load

The distribution of the top 50 hours of load is presented in Figure 3 above. For Customer, the top 50 hours occur exclusively on weekdays. Over half of these hours transpire between noon and 5pm, highly coincident with the electrical grid's peak load. This means that if Customer were able to reduce its peak demands, it would have a high and beneficial impact on the local and regional power grids.

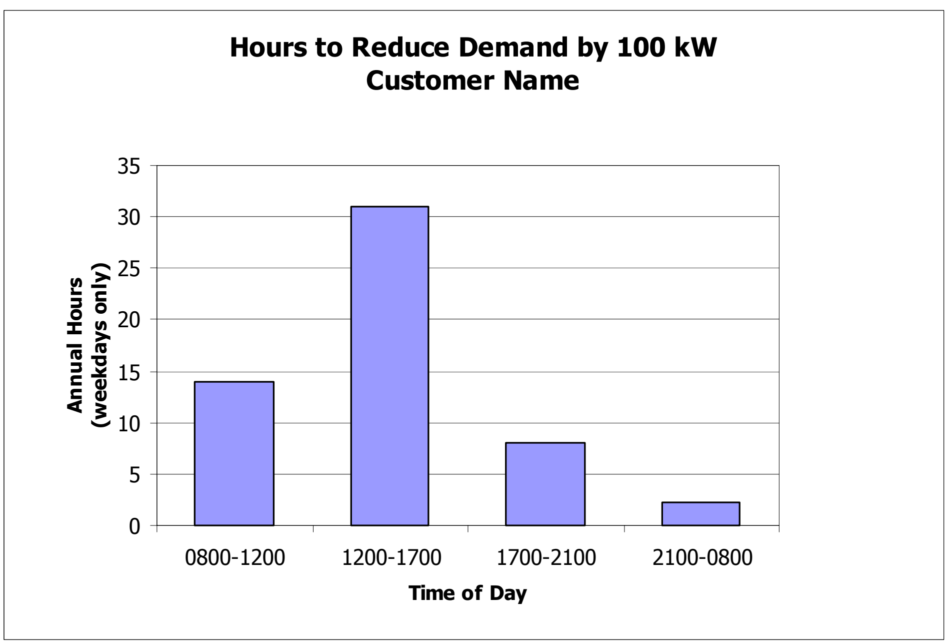

Figure 4: Hours to Reduce Demand by 100 kW

In Figure 4, we depict the number of weekday hours that comprise the top 100 kW of load at Customer. Reducing peak demand by 100 kW at Customer involves just 55 hours, or about 0.6% of the year. Again, these hours are concentrated in the afternoons, but the graph illustrates how relatively few culprit hours are responsible for nearly one-quarter of the facility's peak demand.

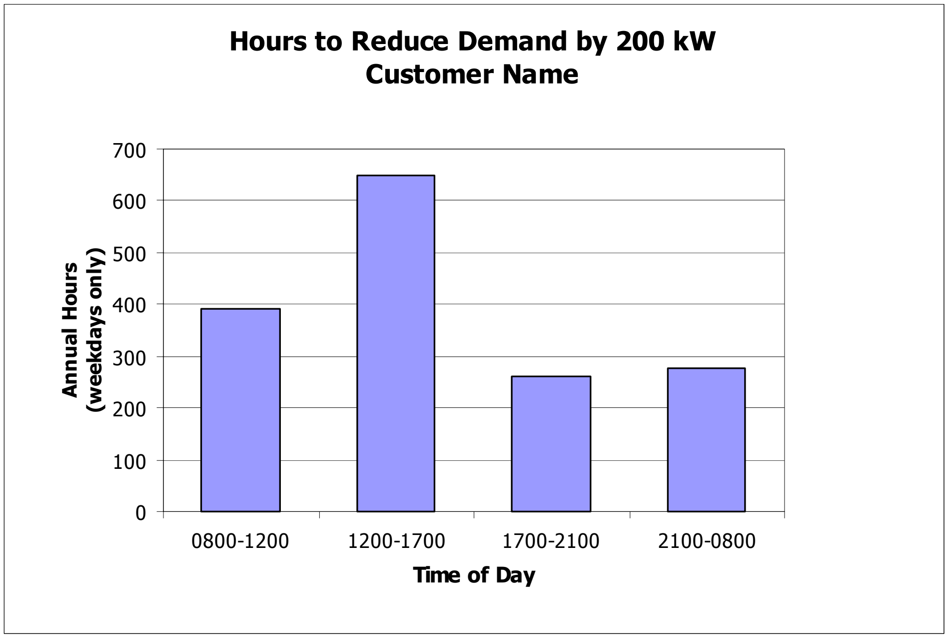

Figure 5: Hours to Reduce Demand by 200 kW

The top 200 kW of load involves dramatically more time: 1,580 hours, or 18% of the year. This high number of hours suggests that a reduction of this magnitude is probably much less feasible for Customer.

Peak Contributing Loads

Undoubtedly, refrigeration is the single most peak-contributing load. This facility peaks during the summer months coincident with warmer ambient temperatures, but the influence of outdoor temperature is not as significant as one might suspect. A fairly significant increase in peak usage coincides with throughput surges, as in the week before the July 4^{th} holiday, but examination of the Energy Print in Figure 1 suggests there is more to the picture.

In particular, energy usage increases at the beginning of November. The warehouse manager provided insight to this load shape feature by revealing that the 57,000-ft2 "package" warehouse (boxed products) has different temperature set points each month, as defined by corporate headquarters. These set points are extremely strict and are monitored closely for quality assurance. In the summer, the packages are stored as high as 69 °F. As pointed out by the warehouse manager, this schedule has the unfortunate effect of putting a sudden burden on the refrigeration systems at the beginning of November, when the CEW room must drop from 55 °F to 43 °F. As those of us in New England can attest, temperatures can remain moderate or even unseasonably warm in early November.

Month	Temp.	Month	Temp.	Month	Temp.
January	40 °F	May	46 °F	September	61 °F
February	40 °F	June	55 °F	October	55 °F
March	40 °F	July	62 °F	November	43 °F
April	40 °F	August	69 °F	December	41 °F

Table 1: Monthly Temperature Set Points for Package Storage

2.4 Load profiles

Figure 6 presents a comparison of the average summer weekday profile to the peak demand week for Customer. The peak week presented in red includes the customer's peak day of Friday, June 27, 2003. In 2003, the Narragansett Electric system peaked on August 22. This system peak week is shown in black below.

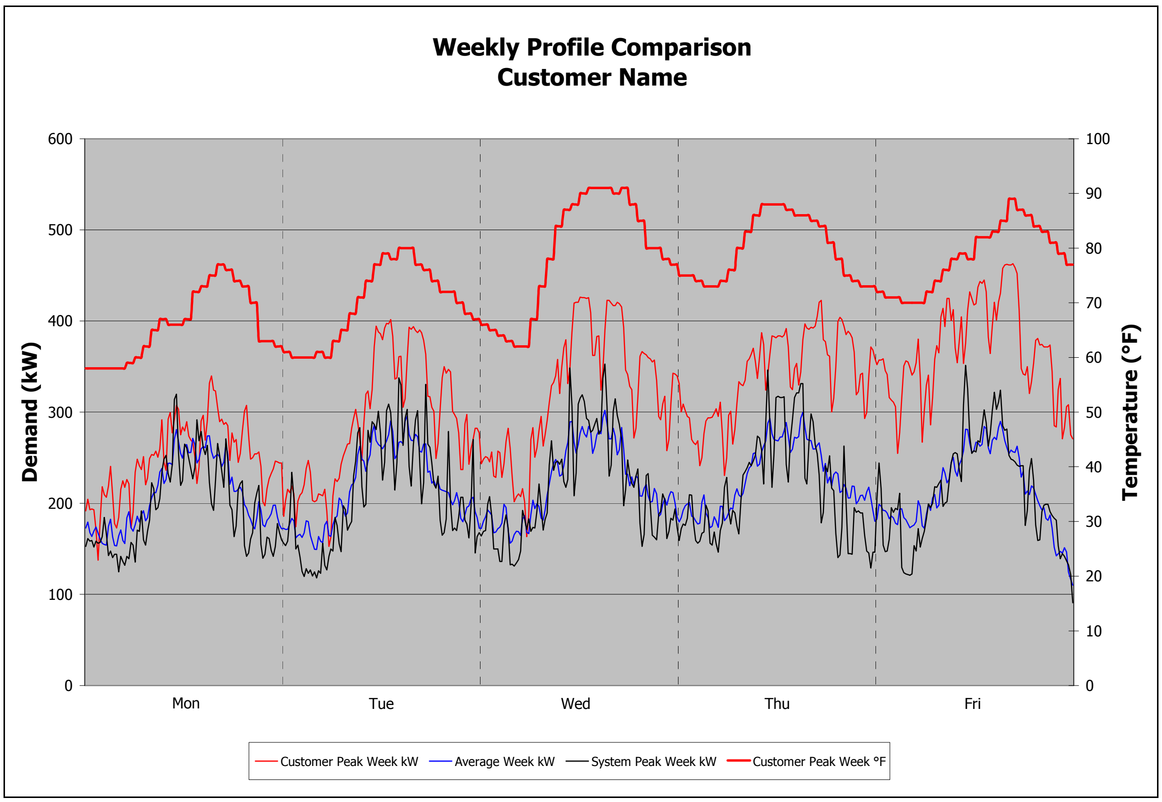

Figure 6: Average/Peak Week Load Curve

Generally speaking, the customer's peak week in red averages about 100 kW higher and is considerably spikier than the average week in blue. On Friday, the peak profile exceeds the average by as much as 207 kW.

Analysts superimposed hourly outdoor temperature (bold red) on this graph to assess correlation with outdoor temperature. The peak profile seems to be somewhat influenced by outdoor temperature, however Wednesday was a slightly hotter day but the peak was set on Friday. Since it has already been revealed that this was the 'push' before the July 4th holiday, the Friday peak is not a surprise. Temperatures were indeed high, but we suspect product throughput was highest on this particular day.

The system peak week (black) is fairly consistent with the average week (blue), suggesting limited external temperature influence. The product surge at the end of June was a significant, peak-setting event.

3 Demand Reduction Opportunities

Demand reduction can be attained through two principal means: load shed and load shift. Figure 7 presents each reduction in a simple graphical example. The base load in blue is the profile if no reduction actions were taken. For both methods, the reduction event itself is shown in the dashed black line.

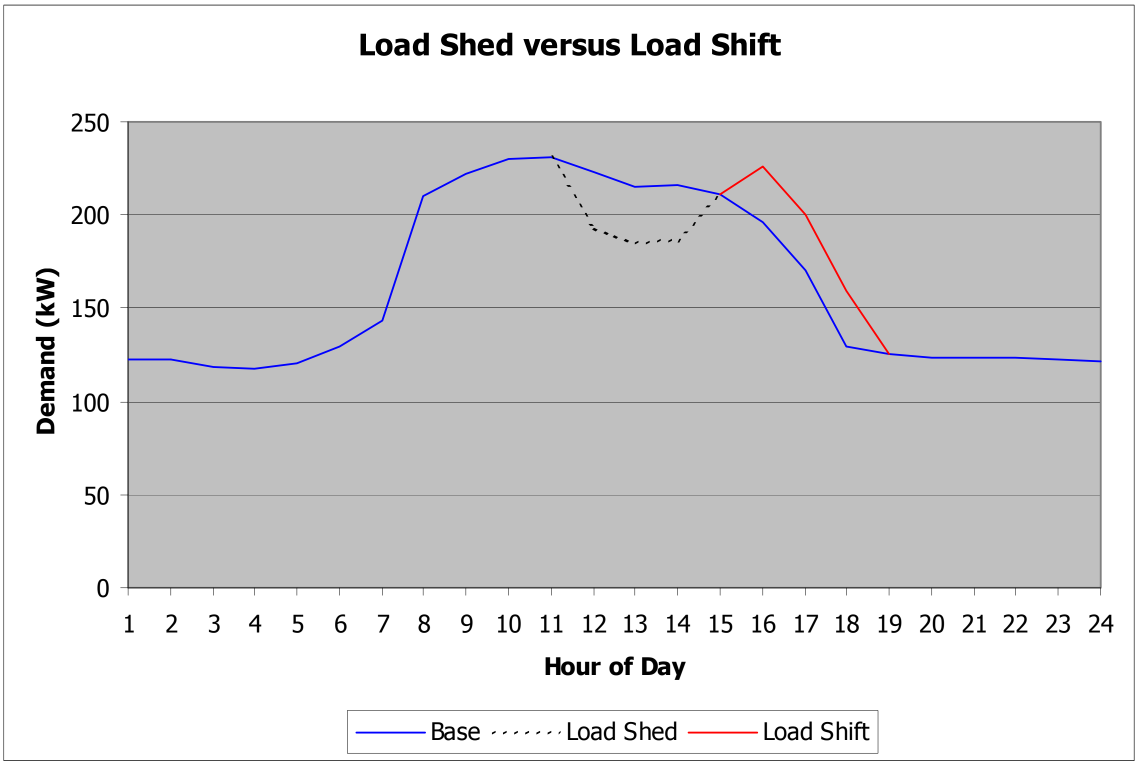

Figure 7: Illustration of Load Shed vs. Load Shift

In a **load shed**, electrical consumption is restored to original levels after the event. Load sheds impose no usage consequences of significance after the event is over. The dashed load shed returns to the base load in blue after the event.

A **load shift** is a demand reduction that necessitates delaying electrical consumption until after the event. A manufacturing firm that shuts down a production line for a few hours but must 'make up' that lost production at the end of the event is enacting a load shift. The dashed-line load shift results in the deferred usage in red to compensate for the duration of the event.

Incidentally, demand reductions by increasing space temperatures on air conditioning equipment exhibit characteristics of each method. The energy usage of cooling systems will rebound after the demand reduction event to restore space temperatures, however the resultant cooling 'backlash' is typically of a shorter duration that the event itself. We categorize such a reduction as a load shed, although it tends to include a small load shift.

3.1 Load Shed

The following load shed opportunities were identified at Customer:

Opportunity 1: Shed lighting load throughout the facility

Actions: Shut off as much lighting as feasible to safely continue operations. In particular, focus attention on high bay 400W HPS fixtures throughout the CEW, cooler, and drive-thru warehouse space. Suggested reductions include:

- 50% of refrigerated warehouse lighting
- 50-100% of hallway lighting
- 20% of office lighting

Alternatively, all lighting except for the night or security lighting circuit could be shed. This would result in considerably more load shed and lower lighting levels. Facility personnel would need to assess feasibility of such a reduction.

Est. Reduction: 32 kW

Costs: Negligible, only minor inconvenience. In fact, there will be an energy benefit to the cooling systems with lower heat gains from the lights.

Benefits:

Bill Credit:	32 kW x $0.50/kWh[1] x 20 hours[2] =	$320.00
ISO-NE Incentive:	32 kW x $0.30/kWh x 20 hours =	$192.00
Bill Savings:	32 kW x 8.128¢/kWh x 20 hours =	$52.02
Total Benefit:		$564.02

Next steps:

- Identify and label lighting circuits for load shed in electrical panels throughout the facility;
- Create a dispatch protocol for these lights and assign personnel to be responsible for shedding unnecessary lighting;
- Perform a feasibility test to see how much demand can actually be shed. Make the demand response preparations and let National Grid know that you are ready to perform a feasibility test. They will assist you in determining the impact of your test.

Opportunity 2: Shed some cooling load by raising temperature set points.

Actions: Raise temperature set points (suggested +4 °F) at the Johnson Controls EMS for the following zones.

- Front offices (1st and 2nd floors)
- Rear offices
- Mezzanine
- Other non-essential areas

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[1] $0.30/kWh is for illustration only: ISO payments will range between $0.10/kWh and the market energy-clearing price, up to a maximum of $1.00/kWh.

[2] 20 hours assumes 5 events per year, 4 hours per event. This is for illustration only; actual hours of demand response could be more or less.

Est. Reduction:	17 kW (approximately 20% of office cooling load)
Costs:	Negligible, only minor inconvenience.

Benefits:

Bill Credit:	17 kW x $0.50/kWh x 20 hours =	$170.00
ISO-NE Incentive:	17 kW x $0.30/kWh x 20 hours =	$102.00
Bill Savings:	17 kW x 8.128¢/kWh x 20 hours =	$27.64
Total Benefit:		$299.64

Next steps:

- Identify the EMS control panels serving these, and any other, non-production spaces;
- Label these control units with the set points and programming procedures to be employed during load shed situations;
- Communicate the potential for an increase in space temperatures to occupants that will be affected by the action;
- Perform a feasibility test to see how much demand can actually be shed.

3.2 Load Shift

The following load shift opportunities were identified at Customer:

Opportunity 3: Shift battery-charging operations until later in the day.

All electric lift equipment has two batteries, one driving the machine and another connected to a charger as backup. There are a total of nine battery chargers, each with one battery in some state of recharging at all times.

Actions:	With day-ahead or early-morning same-day notice, Customer could possibly pre-charge and rotate batteries such that they could endure a four hour demand response event and shut down all of the charging stations.
Est. Reduction:	16 kW (50% of total battery charging power)
Costs:	Negligible, only minor inconvenience.

Benefits:

Bill Credit:	16 kW x $0.50/kWh x 20 hours =	$160.00
ISO-NE Incentive:	16 kW x $0.30/kWh x 20 hours =	$96.00
Bill Savings:	16 kW x 8.128¢/kWh x 20 hours =	$26.01
Total Benefit:		$282.01

Next steps:

- Assign a team leader to be responsible for battery management during peak summer periods.
- When demand response events are anticipated, perform advance charging of both batteries prior to the start of business.
- Shut off circuit breakers feeding battery chargers upon notification of a DR event.
- If charging must occur during an event, activate the minimum number of chargers to endure the predicted operations for the day.

Opportunity 4: Pre-cool the CEW 'package' warehouse. Sufficient reduction of warehouse temperatures in advance of a demand response event may enable Customer to "ride out" a four-hour event with no refrigeration power. The required temperature reduction on a given day will depending upon several factors, including:

- The thermal mass of product in the package warehouse,
- The outdoor temperature and humidity and the number of drive-thru, receiving dock, and CEW room entries,
- The mass and temperature of new product arrivals or departures,
- Any additional loads, such as forklift traffic or lighting.

Actions: Through experimentation, Customer could ascertain the level of pre-cooling (number of degrees below the required set point) in order for the room to sustain four hours without refrigeration and without exceeding the monthly temperature threshold.

- The pre-cooling will require advance consideration, as the product itself – not just the warehouse air – must be pre-cooled to leverage the benefits of thermal mass.
- Maximum financial and efficiency benefit will be attained via pre-cooling in the cooler overnight period prior to the day of concern. Shifting this refrigeration load to the nighttime when office and HVAC loads are minimal will help avoid setting a premature peak.

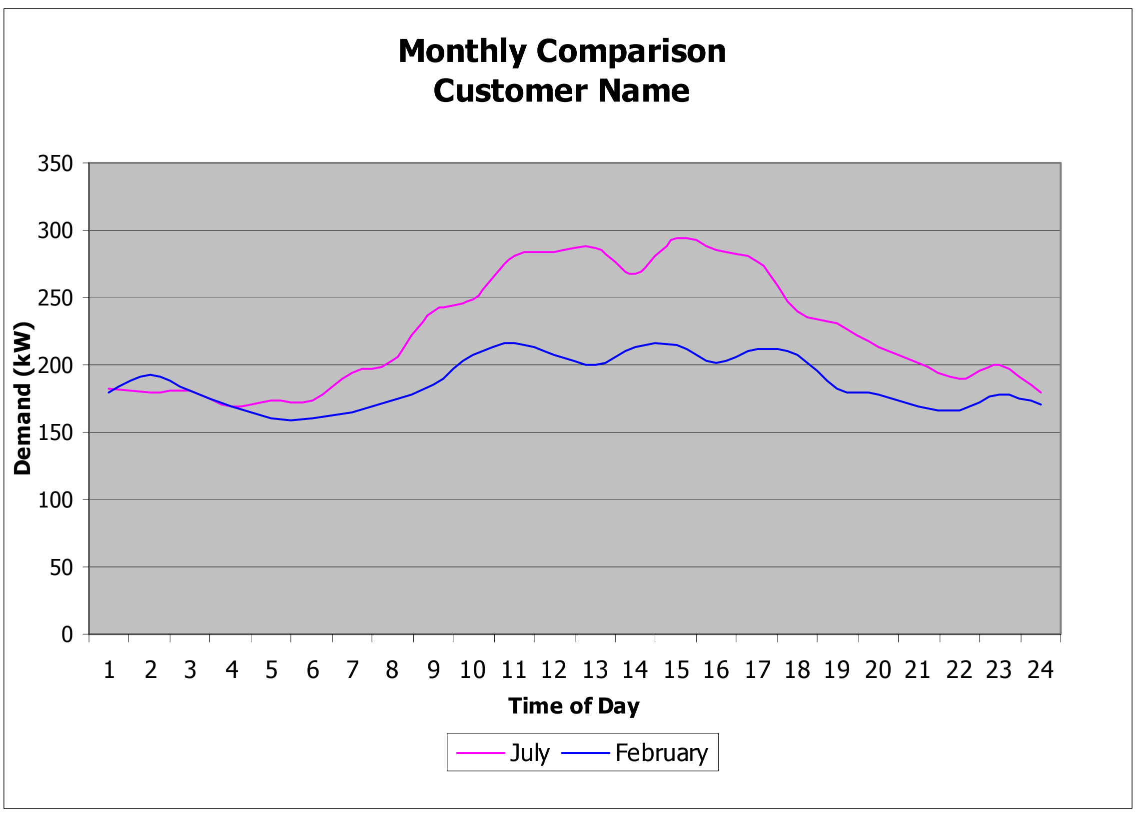

Figure 8: Estimated Impact of Refrigeration Temperature Offset

Est. Reduction: 74 kW

This is the average reduction from 11am-3pm, July vs. Feb. as depicted by Figure 8. This is a conservative estimate of the load shed potential on CEW refrigeration as much of February would be expected to employ 'free cooling'. It does not imply that the CEW is reduced down to 40 °F from 62 °F, rather that sufficient pre-cooling will be employed to keep CEW refrigeration systems effectively off for four hours. The amount of pre-cooling in °F required to endure a four-hour load shed is unknown and should be determined through experimentation.

Costs: Difficult to quantify. The energy usage should offset, and the cost difference will probably be negligible.

Benefits:

Bill Credit:	74 kW x $0.50/kWh x 20 hours =	$740.00
ISO-NE Incentive:	74 kW x $0.30/kWh x 20 hours =	$444.00
Bill Savings:	74 kW x 8.128¢/kWh x 20 hours =	$120.29
Total Benefit:		$1,304.29

Next steps:

- Formulate and communicate pre-cool procedures during demand response events to employees;
- Assign team leaders to be responsible for temperature control throughout demand response events;
- Communicate the importance of a gradual cool-down process to avoid coincident spikes while pre-cooling for an event;
- Starting the night before, gradually reduce CEW set point in increments to mitigate any usage spikes, perhaps by just two degrees per hour. As an initial target, attempt to pre-cool CEW 10 °F lower than the required set point. It will be important to maintain the lower temperature for several hours before the load shed ensure that the product, not just the surrounding air, is chilled down to the pre-cool set point.
- Perform a feasibility test to see how much demand can actually be shed.
- Monitor CEW temperatures throughout the feasibility test and subsequent events. If CEW entries and activities are minimized, we might expect temperatures to increase linearly, i.e. temperatures would rise halfway to the required set point by the midpoint of the event.

Opportunity 5: Lockout electric defrost on refrigeration units.

Actions: There is a substantial amount of electric defrost on the CEW and cooler evaporators. While not particularly likely, there is a possibility for one or more of these electric defrost circuits to engage at an inopportune time during a demand response event. Manually lockout the electric defrost prior to an event.

Est. Reduction: 20 kW (205 kW connected defrost load with 10% estimated diversity factor)

Costs:	Negligible, only minor inconvenience.		
Benefits:	Bill Credit:	20 kW x $0.50/kWh x 20 hours =	$200.00
	ISO-NE Incentive:	20 kW x $0.30/kWh x 20 hours =	$120.00
	Bill Savings:	20 kW x 8.128¢/kWh x 20 hours =	$32.51
	Total Benefit:		$352.51

Next steps:

- Tag defrost circuits in electrical panels and label them;
- Assign personnel for defrost lockout during a demand response event;
- If feasible, perform impending defrost operations in advance of an event.

Demand Response Summary

Opportunity	Response Action	Est. kW Reduction	Potential Benefit
1	Shed	32	$564.02
2	Shed	17	$299.64
3	Shift	16	$282.01
4	Shift	74	$1,304.29
5	Shift	20	$352.51
TOTAL		**159**	**$2,802.47**

3.3 Energy Efficiency

No standard energy efficiency opportunities were identified at Customer that have yet to be considered. Most of the fluorescent lighting at the facility is comprised of T8/electronic ballast. Some areas in the rear of the facility still have T12 lamps and standard ballasts, but facility management says that plans are underway to retrofit this lighting as well.

3.4 Further Study

The high bay warehouse, cooler, and dock lighting is all currently high-pressure sodium. While moderately efficient, considerable savings could be achieved by retrofitting these fixtures with pulse-start metal halide and dimmable ballasts controlled by motion sensors. A study should be commissioned to estimate the savings potential of occupancy and/or dimming control, as there are over 100 fixtures and usage patterns vary greatly. For any lighting improvement in these spaces, the interactive effects on the refrigeration system (reduced heat gain to the cooled space) will be quite beneficial.

Electric defrost is employed at Customer, and its selection is usually that of equipment first cost. Hot-gas defrost may be considered for existing and future units to reduce these high intermittent defrost demands.

All of the battery chargers at Customer function at multiple voltage levels. Currently, the main battery-charging bank is served off a 100A 208V 3-phase circuit downstream of a 480V step-down transformer. Feeding the battery chargers at 480V 3-phase should be more efficient at the charger, will result in fewer distribution losses on the way to the chargers, and will eliminate the inefficiency (heat loss) of the step-down transformer. It would be a fairly simple and inexpensive electrical job to reroute 480V 3-phase power and install 480V circuitry to the battery charging stations. The transformer would still supply 208V 3-phase for some miscellaneous loads, but the loading on the transformer would result in fewer transformer losses, less heat gain to space, and hence refrigeration savings. Unless the transformer was specified to trap problematic harmonics from the chargers, this retrofit should be studied further with consideration given to power quality.

4 Conclusion

Although no demand response events were called in the area in 2003, customers in your region are being asked to seriously consider their abilities to shed demand in the event of distribution constraints or very high demand. We foresee no cause for concern this summer, but this report is being provided to inspire and facilitate some reasonable contingency planning in the event that the local grid becomes constrained or regional demand approaches supply capabilities.

Please review the information and recommendations contained within this report, contact your Account Manager about enrolling in the local demand response program and the ISO New England program, and develop a custom response plan for your facility. It is important to make these preparations in advance, because if demand response is called for, time will be of the essence. Upon request for demand response by Narragansett Electric or ISO New England, Customer ought to initiate all applicable and practical reductions.

Customer is one of many receiving demand response audits and enrollment recruitment. Even if each customer can only reduce load a small amount, the combined and coordinated effort will be rewarded through performance incentives and grid stability.