Energy Savings in the Citrus Industry: Proposed Solutions

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ABSTRACT

The orange and grapefruit juice industry is a major energy consumer in Florida. The current projected profit margin in the citrus business is rather tight; and consequently many production cost reduction alternatives are under exploration, like the use of organic agriculture, irrigation systems, fertilizers, new technology, etc. On the growers' side, profits will be severely impacted if the Free Trade of the Americas (FTA) proposal is enacted. On the orange juice producers' side, this means that the U.S. tariff on imported orange juice would be reduced or eliminated under FTAA. The prognosis under this situation is not good, and the foreseen result is that orange juice prices will drop significantly.

In this work we propose a reduction of citrus juice production cost through the establishment of energy saving measures, reducing energy costs, and pollution. For this purpose we review the current energy usage patterns of a number of Florida juice (orange and grapefruit) manufacturing facilities, at which the University of Florida Industrial Assessment Center (UF-IAC) has performed energy audits. Their current energy usage patterns (heat and power) associated costs, energy indicators, and previously recommended energy savings measures are discussed. We propose a set of energy savings measures outlining some energy indicator values and benchmarks, which will reduce production costs ($/unit). Finally, key energy end uses and innovations are explored.

Introduction

The orange and grapefruit juice industry is one of the largest manufacturing sectors in Florida. The current condition of the market puts these and related manufacturing facilities under stress to continue production at reasonable profit margins in a market that is getting highly competitive. Indeed, and for some years now, some Latin-American countries like Brazil are strongly dictating the prices by penetrating the national market.

The cost of manufacturing citrus juice depends on the cost of growing and picking the fruit from the groves, extracting fresh juice, and producing concentrate. Changes in policies (FTA) are difficult to achieve, as they take a long time to become reality, and manufacturers usually want to obtain savings as soon as possible. In this work we present a rather different approach. We believe that an internal review of operations could help to improve operations and generate some savings. The present study is based on energy audits performed by the University of Florida Industrial Assessment Center for a set of citrus juice manufacturing facilities in central Florida. In this study we analyze the general background of these facilities, their energy usage patterns, and recommendations made by the UF-IAC to reduce energy consumption. This paper looks for general energy management trends that can in turn be used as benchmarks by citrus manufacturers, through a set of indicators. These will directly reflect not only current energy consumption trends along the manufacturing process, but possible energy reductions, and hence reduction of production costs as well, and cost per unit.

It has to be pointed out that the results presented here do not represent a definite perspective of the energy consumption of the studied type of facilities, but they rather show trends. In Table 1 we present the profile of the facilities considered. We have included the Standard Industrial Classification (SIC) codes, sales figures, annual production, size of facilities and production cost, number of employees, and their participation in the State of Florida electricity tax exemption program. The number in parenthesis indicates the number of energy assessment recommendations (AR's) made during the energy assessment (see Tables 3 - 6 for details). Finally, the percentage that these AR's represent with respect to the total electric energy consumption is also displayed. Averages for each set of SIC code are displayed.

Table 1. Company Profiles

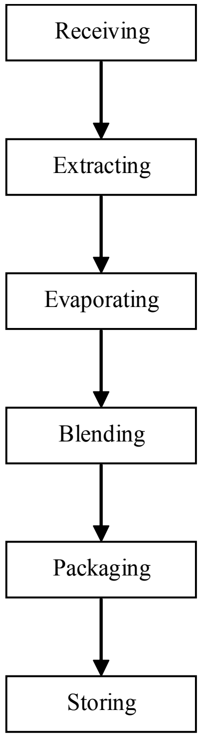
SIC	Plant	Sales ($/yr)	Annual Production	Production Area		Emps.	Taxes Prog.	E. Savings ($/yr)	% E Savings
				ft^2	\$/ft^2				
2033	A	45,000,000	7,000,000 cases	142,283	316.27	175	Yes	86,741 (6)	10.83
	B	50,000,000	25,000,000 lbs of Conc.	300,000	166.67	150	Yes	216,126 (5)	26.98
	C	100,000,000	14,000 boxes of fruit juice	645,712	154.87	150	Yes	124,460 (8)	15.54
	D	140,000,000	3,400,000 gallons of Conc.	100,341	1395.24	140	Yes	189,709 (9)	23.68
			Average					**$154,259**	**19.26**
2037	E	40,000,000	3,875,000 gallons of Conc.	350,000	114.29	100	Yes	68,351 (3)	8.53
	F	15,000,000		100,000	150	90	Yes	25,002 (5)	3.12
			Average					**$46,676**	**15.45**
2087	G	25,000,000	4,830,000 gals. frozen Conc.	30,000	833.33	25	No	17,324 (4)	2.16
	H	24,000,000	4,000,000 boxes of juice	31,000	774.19	70	Yes	73,317 (6)	9.15
			Average					**$45,321**	**5.66**

General Background

The manufacturing processes performed in these facilities are described below. This description is not intended to be complete and detailed, but rather to provide general information on the processes with a focus on energy requirements. The main steps, shown in Figure 1, are:

1. *Receiving:* The fruit (or concentrate) is received (generally in trailers). The fruit is transported into the facility by a conveyor system.
2. *Extracting:* The juice (and pulp) is extracted by centrifugal extractors. (The rate of extraction is usually about 150-200 fruits per minute per extractor). In general the process is controlled by computers.
3. *Evaporating:* The concentrate is produced through evaporation by thermally accelerated short-term exposure. In general the heat exchanger here is used to chill concentrate from 45°F to 20°F.
4. *Blending:* The concentrate is blended with pre-mixes. The by-products produced at this stage are peel oil, pulp cells, cattle feed, essence oil, aroma and d'limonene. Most of these are sold and the rest are internally used in the process. Agitation tanks are used for this process.
5. *Packaging:* In most facilities 55 gallon plastic drums capacity are used to pack concentrate for shipment. All other packaging is done in plastic bags and then placed inside card board boxes. A barrel line is used to fill and label drums at a given rate (average is 40 drums/hour). Drums are carried by trucks.
6. *Storing:* The storing is done in holding tanks located inside large refrigerators. The refrigerator temperature is maintained between 15°F and 18°F. In addition, at the end of the process, shipping of the juice is performed. The concentrate is shipped by trailers either to customers or to bottling facilities by the same company.

Figure 1.



Inspections are a crucial part of the process, not only from the perspective of quality control, but also from the regulatory stand point. In general, after receiving, the fruit is washed by a soap solution while on conveyors. The quality of grapefruits is tested by the US Food and Drug Administration's (FDA) through an on-site office. The FDA officers test the quality of fresh fruit coming into the facility for pH levels, taste, sugars content, etc. Usually there is also some visual inspection done at the receiving station by in-house selected personnel.

Energy Consumption

The energy consumption of the facilities differs from one to the other, even if they manufacture the same product. Nevertheless, a closer look to their energy consumption shows that some trends arise. It also allows the relative merits of energy conservation and load management to be assessed. In this section we will discuss these trends in terms of the energy used by type of equipment, and other features like energy costs as well.

Utility Companies

The companies considered receive their utility service (electricity and natural gas) from a variety of utility companies in Florida. Some of them are rural, municipal, or investor-owned utilities. On average the costs are similar but there are some marked differences in their energy rate profile, as shown in Table 2**.** While most of the large utilities offer good financial incentives to companies that install energy and demand saving equipment, midsize ones are starting to offer little incentives for the adoption of new technology (like solar energy for water heating), and small utilities offer no incentives. It is indeed a very good practice to stay in close touch with the utility company and its available programs.

Energy Data

Table 2 shows energy usage and costs for electricity, natural gas and other fuel types used in these facilities. From here it becomes clear that, on the average, the cost of electricity is very reasonable. However there are still some exceptions due to small utilities as shown by the rates of plants D and F. Would de-regulation help to reduce these values? At the end of 2002 and beginning of 2003 the cost of natural gas increased about 300%, which should result in a lagging cost increase in electricity in the near future. Would then a combined heat and power system be a more attractive solution? The question will remain for awhile, and we will discuss it in a future work.

Table 2. Energy Rate Profile Prior to Energy Audits

SIC Code	Plant	Electricity			Natural Gas	Other Fuel	Energy Costs
		$/kW/month	$/kWh no Demand	$/kWh with Demand	$/MMBtu	$/Gallon	per Sales (%)
2033	**A**	2.17	0.041	0.045	5.60		2.35
2033	**B**	2.45	0.041	0.061	2.65		3.28
2033	**C**	1.66	0.043	0.047	7.83		15.19
2033	**D**	8.59	0.064	0.083	1.10		0.80
Average		**3.72**	**0.047**	**0.059**	**4.295**	**0.000**	**5.40**
2037	**E**	1.79	0.037	0.042		0.453	0.60
2037	**F**	8.85	0.054	0.075	10.93		5.30
Average		**5.32**	**0.046**	**0.059**	**5.465**	**0.227**	**2.95**
2087	**G**	3.96	0.053	0.065		0.449	0.58
2087	**H**	1.58	0.044	0.048	4.05		3.84
Average		**2.77**	**0.049**	**0.057**	**2.025**	**0.225**	**2.21**
Total Average		**3.94**	**0.047**	**0.058**	**3.928**	**0.150**	**3.52**

Citrus juice manufacturers have different demand and energy costs. Average values are shown in Table 2. We use these costs in the economic analysis. For those cases in which the demand reduction cannot be quantified (selected recommendations), we use the cost of energy including demand. These costs include taxes and are all based on a twelve month period. We see that there is a marked difference in costs among the groups of SIC codes.

We see from the average of these values that the different SIC code groups have some similar values for energy, but not for demand, which makes the difference among them. We use these values to compute savings for the recommendations to be made.

Equipment: Electric Cost Distribution

As regular practice, and to identify electric energy usage by equipment type, the UF-IAC has developed a software program package, the Interactive Energy Balance (IEB) which, after inputting electric bills and equipment data, performs an energy balance for the user. This is a list of all equipment that uses electricity and their consumption operational patterns. The total is finally compared with the actual electric energy bills (usually the previous 12 months), requiring a deviation of less than or equal to 1%. We have collected these totals and averages and put them in a Pareto format, shown in Figures 2-4, for ease of analysis. From them it becomes clear that chillers, motors, air conditioners, and compressors are the main electric energy consumers. They also suggest that facilities with an SIC of 2033 are much larger electric energy consumers than those with SIC 2037, and 2087 by approximately a factor of 5. This is roughly proportional to the differences in sales figures for the three different types of plants. As noted above, the inconsistent cost of natural gas makes it rather difficult to attempt to take averages. As a consequence we will concentrate our analysis on electrical energy consumption.

Figure 2. Pareto Charts for SIC 2033

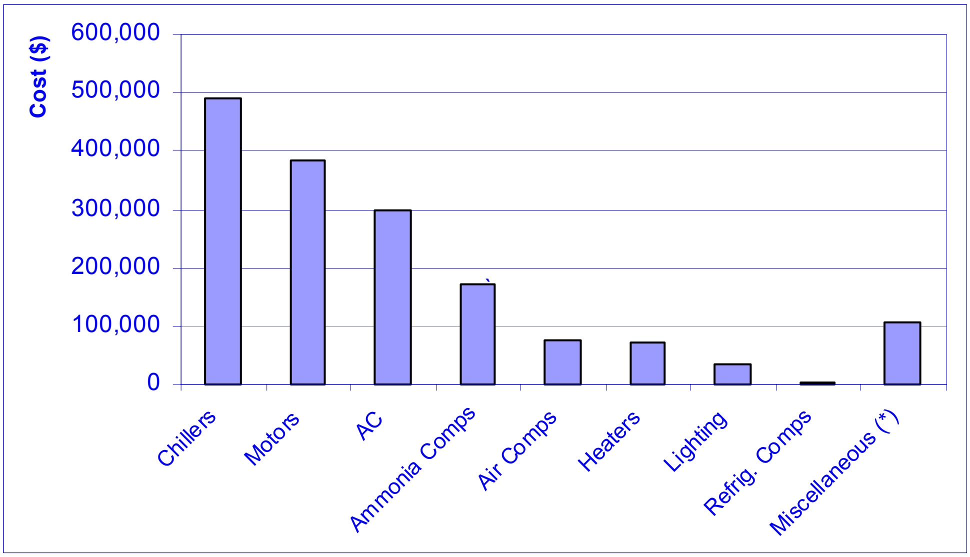


Figure 3. Pareto Charts for SIC 2037

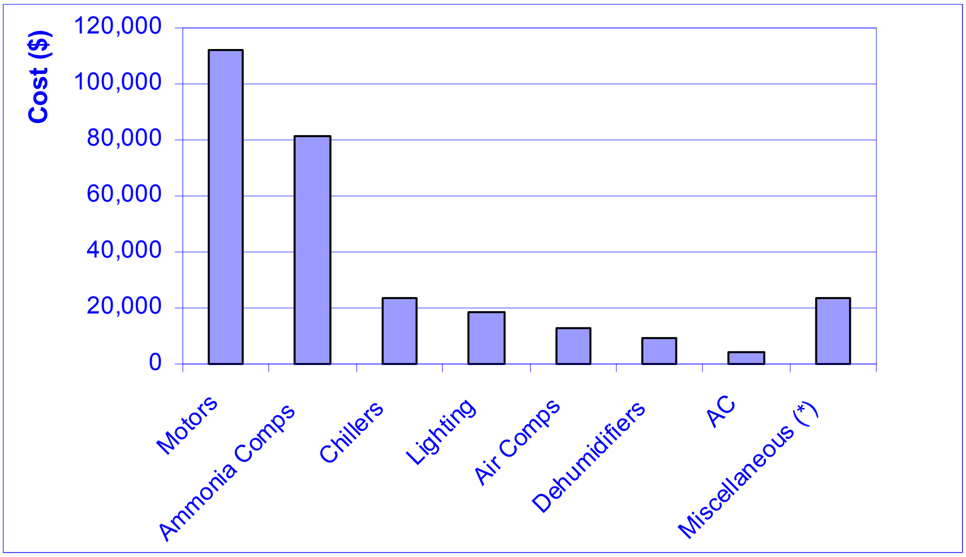
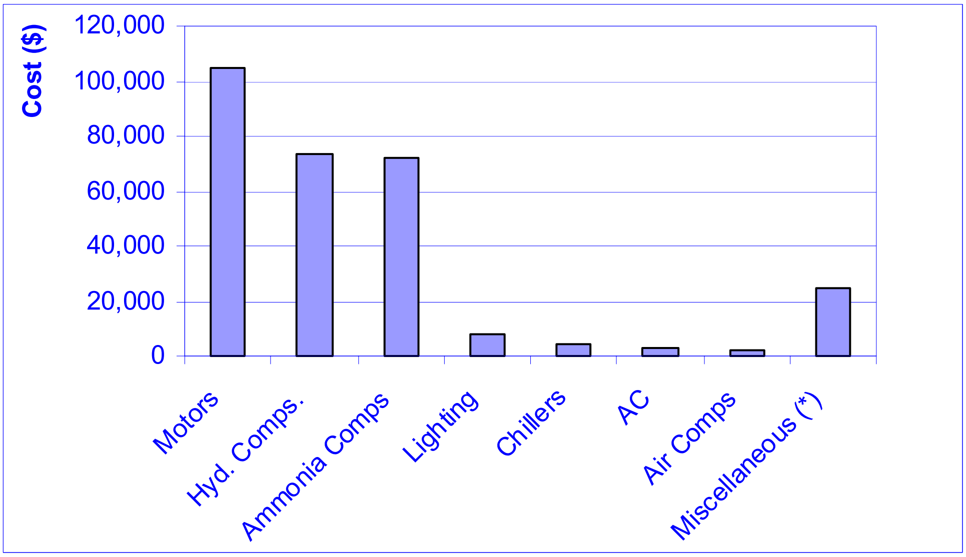


Figure 4. Pareto Charts for SIC 2087



Proposed Measures

As the energy assessments were performed, many different recommendations were made for each plant. It must be pointed out though that these energy audits lasted only one day, during a time at which the facilities were all fully operational. Additionally it should be noted that these facilities have seasonal fluctuations due to the nature of their business. In Table 3 we have summarized the energy recommendations made for each facility. The UF-IAC made additional savings recommendations, not listed here, in the areas of waste handling and productivity enhancement. In Tables 4-6 the proposed energy (kWh), demand (kW), cost ($/yr) savings, associated implementation cost, the expected simple payback period (SPP), and the return on investment (ROI) for each SIC code type of facility are displayed all of which are a consequence of the energy savings (ES) and demand reduction (DR). Here we have used the different costs of energy and demand shown in Table 2.

Data Analysis

Based on the data, we are now in a position to estimate potential savings for the type of facilities considered; with the caveat that they are suggestions that show trends and that they represent a fraction of these Florida industries. To show potential savings we have considered, for each particular SIC, the average of energy savings, and the fraction that corresponds to the energy usage for each type of piece of equipment listed shown in Table 1.

Consequently, we can write the fraction of savings $F_{i,j}$ as follows:

$$F_{i,j} = \langle S_j \rangle \times [\, C_j / \sum_{j=1} T_j \,]$$

Table 3. Assessment Recommendations for Energy Savings by SIC Code

Assessment Recommendations	2033	2037	2087
Install High Efficiency Lighting	✓	✓	✓
Reduce Lighting in Selected Areas	✓		
Turn Off Lights and AC	✓		
Install Occupancy Sensors		✓	
Remove Unnecessary Lights	✓		
Schedule Freezers Lights Use	✓		
Turn Off Outside Lights	✓		
Install Skylights and Sensors	✓	✓	
Implement Lights Management System			✓
Install High Efficiency Motors	✓	✓	✓
Replace V Belts with Cogged V Belts	✓		
Adjust Boiler Air/Fuel Ratio	✓		
Increase Frequency of Boiler Tune-up		✓	
Retrofit Gas Fired System	✓		
Repair Compressed Air Leaks	✓	✓	
Provide Cooler Air for Air Compressor	✓		
Reduce Compressed Air Pressure	✓		✓
Repair Steam Leaks	✓		
Recover Waste/Exhaust Heat	✓		✓
Install Combined Heat and Power System	✓		
Insulate Facility Roof	✓		
Insulate Roof of Tank Farms	✓		
Install New Refrigeration System		✓	
Change Feed Mill Schedule		✓	✓
Turn Off Unused Equipment	✓		✓
Apply for Electricity Tax Incentive			✓

Where,

$F_{i,j}$ = Fraction of savings.
= Counters: i is for SIC: 1 =2033, 2=2037, 3=2087
j is for the type of piece of equipment. It runs from 1 to 11 as of the sequence shown in Tables 4-6 (first column).
$<S_i>$ = Average of Savings (kW, kWh, cost)
C_j = Current Consumption (kW, kWh, cost)
T_j = Total Current Distribution according to piece of equipment and SIC

In this fashion we see how the energy is being distributed, and hence we obtain proposed energy, demand, and associated cost savings that we can now directly compare with current usage. The savings (energy, demand, and cost) are shown in Tables 4 - 6. We perform our analysis by type of energy consumers that are typically present in most manufacturing facilities. We also list the cost associated to the implementation of our recommendations, simple paybacks, and return on investment for all three SIC codes.

Table 4. Energy (E) Assessment Recommendations Savings for SIC = 2033

	Savings			Implemen-	SPP	ROI
	kWh	kW	$/yr	tation Cost ($)	years	%/yr
Lighting	111,433	29	6,546	14,274	2.2	46
Motors	1,136,974	52	56,087	30,181	0.5	186
Air Cond.	1,210,020		66,914	75,000	1.1	89
Air Comps.	284,033		15,707	1,050	0.1	1,496
Ammonia Comps.	541,672		29,954	45,000	1.5	67
Hydraulic Comps.						
Refrig. Comps.	17,242		953	2,500	2.6	38
Chillers	2,108,067		116,576	40,000	0.3	291
Heaters	77,582		4,290	31,741	7.4	14
Dehumidifiers	1,557,563	555	98,459	15,000	0.2	656
Miscellaneous	416,040		23,007	16,000	0.7	144
TOTAL Savings	**7,460,625**	**636**	**418,494**	**270,745**	**0.6**	**155**

Table 5. Energy (E) Assessment Recommendations Savings for SIC = 2037

	Savings			Implemen-	SPP	ROI
	kWh	kW	$/yr	tation Cost ($)	years	%/yr
Lighting	20,496	15	1,876	5,180	2.8	36
Motors	107,774	11	5,689	5,637	1.0	101
Air Cond.	3,485		206	0	-	-
Air Comps.	13,767		812	250	0.3	325
Ammonia Comps.						
Hydraulic Comps.						
Refrig. Comps.						
Chillers	25,350	13	1,983	10,000	5.0	20
Heaters	8,826	103	6,975	0	0.0	-
Dehumidifiers						
Miscellaneous						
TOTAL Savings	**179,697**	**142**	**17,540**	**3,511**	**1.5**	**66**

Table 6. Energy (E) Assessment Recommendations Savings for SIC = 2087

	Savings			Implemen-	SPP	ROI
	kWh	kW	$/yr	tation Cost ($)	years	%/yr
Lighting	16,995	6.9	1,063	951	0.89	112
Motors	114,369	40.8	6,959	24,939	3.58	28
Air Cond.	2,735		156	0	Immediate	-
Air Comps.	2,424		138	0	Immediate	-
Ammonia Comps.	77,337		4,408	8,500	1.93	52
Hydraulic Comps.	86,578		4,935	4,000	0.81	123
Refrig. Comps.						-
Chillers	4,843		276	1,000	3.62	28
Heaters	51,092		2,912	0	Immediate	-
Dehumidifiers						-
Miscellaneous	27,452		1,565	1,000	0.64	156
TOTAL Savings	**383,824**	**47.7**	**22,412**	**40,390**	**1.80**	**55**

Descriptors

In this section we concentrate on understanding how the electric energy is used by the different pieces of equipment in the facilities. Obviously some consume more energy than others, and as a consequence are more relevant for an energy conservation study, and to describe the energy consumption in the plant. Accordingly, we recognize this by first classifying the energy consumers by the kind of equipment, as we did in Tables 4-6 (1 = Lighting; 2 = motors, 3= AC, etc.). Secondly, we assign them a specific weight, whose value will serve to describe the electric energy consumption; we will call them electric energy usage *descriptors*.

We compute these descriptors ($f_{i,k}$) by taking for each SIC the average consumption value of a given type of equipment $\langle L_{i,k} \rangle$ and divide it by the sum of all. This is:

$$f_{i,k} = \langle \mathbf{L}_{i,k} \rangle / \sum_{i=1}^{11} L_{i,k}$$

Notice that the counter *i* run for all equipment considered and shown in Tables 4-6. The counter *k* accounts for demand ($k = 1$), energy ($k = 2$), and cost savings ($k = 3$). For each SIC considered these descriptors must satisfy the following necessary condition:

$$\sum_{i=1} f_{i,k} = 1$$

The calculated values of computed *descriptors* for demand, energy, and costs for each SIC are shown in Table 7. In it, the highlighted values indicate again the major contributors that better describe the energy usage in the plants studied. The corresponding energy consumption areas are different for each type of SIC, as expected. For SIC 2033, motors, air conditioning and chillers consume the most energy. Instead, motors and the ammonia compressors are the main energy users for SIC 2037. Finally, for SIC 2087, the big energy consumers are again the motors, the ammonia compressors, and hydraulic compressors. On average, the equipment represents 74%, 79%, and 84%, respectively, of all the electric energy consumed in these facilities.

These descriptors multiplied by the demand, energy, or cost associated with the equipment (lights, motors, chillers, etc.) of the SIC group considered, accounts for the total electric energy use for them. However, and as discussed above, there are some particular descriptors that account for most of the demand, energy, and cost savings. As an example, below we show the demand, energy and cost savings associated with SIC 2033, represented through the use of the corresponding descriptors, all taken from Table 7.

Table 7. Energy Distribution Descriptors within each SIC

	2033			2037			2087		
	kW	kWh	Cost ($)	kW	kWh	Cost ($)	kW	kWh	Cost ($)
(1) Lighting	0.017	0.018	0.021	0.046	0.067	0.071	0.030	0.051	0.027
(2) Motors	0.255	0.185	0.236	0.511	0.355	0.428	0.383	0.344	0.359
(3) Air Cond.	0.209	0.197	0.182	0.021	0.011	0.015	0.017	0.008	0.010
(4) Air Comps.	0.045	0.046	0.046	0.026	0.045	0.050	0.010	0.007	0.008
(5) Ammonia Comps	0.107	0.088	0.105	0.339	0.425	0.310	0.203	0.232	0.245
(6) Hydraulic Comps							0.250	0.260	0.250
(7) Refrig. Comps.	0.002	0.003	0.002						
(8) Chillers	0.298	0.344	0.300	0.042	0.063	0.091	0.031	0.015	0.015
(9) Heaters	0.048	0.050	0.044						
(10) Dehumidifiers				0.015	0.033	0.036			
(11) Miscellaneous	0.017	0.068	0.064				0.076	0.083	0.085
TOTAL	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Demand (k=1): $f_{i,k} = f_{i,1} = f_{2,1} + f_{3,1} + f_{8,1} =$ **0.255 + 0.209 + 0.298 = 0.762**

Energy (k=2): $f_{i,k} = f_{i,2} = f_{2,2} + f_{3,2} + f_{8,2} =$ **0.185 + 0.197 + 0.344 = 0.726**

Cost (k=3): $f_{i,k} = f_{i,3} = f_{2,3} + f_{3,3} + f_{8,3} =$ **0.236 + 0.182 + 0.300 = 0.718**

As it can be seen these descriptors describe the parameter of interest (demand, energy, and cost savings), which is an average of 73%. The advantage is that we focus only on three of the eleven areas we may have considered. For, SIC 2033 and 2087 three descriptors are needed; whereas 2 are required for SIC code 2037.

Conclusions

We have presented a review of the current energy usage patterns of a number of Florida juice (orange and grapefruit) manufacturing facilities, at which the University of Florida Industrial Assessment Center (UF-IAC) has performed energy audits. Their current energy usage patterns (heat and power), associated costs, energy indicators, and recommended energy savings measures have been discussed.

Through the analysis of the available data, we have presented a consistent set of measures that can be taken to reduce the production cost of citrus juice through the establishment of energy saving measures or simply, reducing energy costs. Moreover, and for the SIC's considered, we have identified the areas that should be prioritized through a Pareto approach.

In our study we have proposed the use of descriptors, whose advantages consider narrowing down the areas in which an energy management program should concentrate. In other words, we have made a Pareto identification of energy consumption areas to which priority should be given. Moreover, we believe that through this process, we are providing also a tool for benchmarking the SIC codes considered. In essence, we foresee that facilities with SIC codes as those considered here, can easily identify savings possibilities, and by comparison benchmark their operations. Table 7 provides the necessary information for this task.

Heat recovery is an attractive idea, as currently the cost per MMBtu coming from electricity is approximately (average) 2.5 times higher than the one from natural gas. As discussed at the very beginning, the cost of natural gas has gone up, but we believe that this fact should encourage heat recovery opportunities, as recommended to practically all the plants considered here. Finally, energy conservation opportunities do provide a reduction in pollution in a somewhat direct mode. Indeed, electricity is an on-time commodity, hence each time that a plant reduces its electric energy consumption, the corresponding utility company burns less fuel with the consequent pollution reduction. Hence this work, as others in energy management, has a dual purpose, this is, energy savings and environmental conservation.

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References

2002 Directory of Florida Industries. Harris Infosource. Twinsburg, Ohio.

S. Krishnamurty, D. Kirmse, D. Schaub, and C. Cardenas-Lailhacar, Vol. 1. July 2001. *An Interactive Energy Balance: A Case Study*. New York. ACEEE Proceedings Summer Study on Energy Efficiency in Industry,

Cristian Cardenas-Lailhacar, November 2002. *Interactive Computer Tools for Energy Auditing*. Orlando. Proceedings Business Energy Solutions Expo.

Cristian Cardenas-Lailhacar, Shankar Venkat, Diane Schaub, Barney L. Capehart, Lynne C. Capehart, and Klaus-Dieter E. Paulik, *An Energy Savings Case Study Using the Interactive Energy Balance.* In preparation.

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