This paper discusses the energy savings potential of a plastic products manufacturing facility in Central Florida. The authors performed an energy audit of the facility as part of a contract with the U.S. Department of Energy to perform industrial energy assessments through DOE s Energy !nalysis " Diagnostic Center program. #n addition to a survey of the traditional energy$using e%uipment such as motors and lighting& the audit team loo'ed at energy used in the process and recommended ten energy savings measures which could save the company slightly over ten percent on its electric energy (ills.

The facility manufactures a molded plastic product which is distri(uted nationwide. The company has a(out 1)* employees& and an annual sales figure of a(out +1, million.

The facility has one (uilding with a total area of appro-imately .*&*** s%uare feet. The (uilding has appro-imately /*$foot ceilings and has a corrugated steel roof. The ceiling has 1 to 0 inches of insulation.

The offices are air$conditioned in sections (y nine roof$top units. The main production floor is cooled (y seven high$efficiency& roof$top air conditioning units. #t is air conditioned to maintain low humidity for high product %uality. The lining room uses a separate high$efficiency unit located (ehind the (uilding. The warehouse is not air conditioned.

The production floor of the facility operates 0/ hours a day& (etween) and 1 days a wee'.

The electric (ills for this company for 2ay 1,,0 through !pril 1,,3 were appro-imately +)04&*** for ,&*1.&*** 5 6 7. This is an average cost of +*.*). per 5 6 7. The average monthly demand was 1&/., 5 6& and the average demand cost was +1*&*)3 per month. For Energy 2anagement 8ecommendations 9E2 8s: which involved a reduction in pea' demand with no improvement in energy efficiency& we used an average demand rate savings of +4.1) per 5 6 per month 9which includes ta-es:.

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[1] 6e would li'e to ac'nowledge the wor' of two other people in preparing this paper. ;rent Crawford was the team leader who conducted the audit and prepared the audit report. Sumit 8ay helped with the DOE$0 analysis.

6e used the average electricity cost to perform the economic analysis of all E28s that involved improved energy efficiency e-cept for e%uipment that is operated off$pea'. #n that case& we used an electricity cost of +*.*/)<567 and did not consider the demand cost.

This companys ma=or manufacturing operation is in=ection molding. The facility has twenty$si- in=ection molding machines to mold and form the final product. Some of the molding machines are varia(le$volume hydraulic while the ma=ority are fi-ed$volume. Cooling tower water is used to cool the circulating oil& and chilled water is used to cool the hydraulics.

>lastic pellets arrive (y railcar and are vacuum$conveyed to separate silos located outside the (uilding. The pellets are fed automatically from the silos into each molding machine using vacuum suction. The finished products are then pac'ed in (o-es and put in the warehouse.

The company has two secondary processes. Some products re%uire a compressed air process for finishing. Others are placed on a conveyer (elt and printed with an in'ing machine. U? lamps dry the in' instantly.

Ta(le # summari@es the energy management recommendations made (y the E!DC audit team. #f the company implements the recommended measures& it will reali@e an annual savings on its energy (ills of appro-imately ..4&*** 567 for a cost savings of nearly +))&***. The total implementation cost for these measures& which is reduced (y applica(le utility re(ates& would (e a(out +)*&*** and the simple pay(ac' period is a(out eleven months.

The total savings shown in Ta(le # is not the sum of all the measures shown. E28s 4 and 1 are mutually e-clusive measure& and we recommended only E28 4. #mplementation of E28 , is uncertain& so it is not included in the totals either. #n addition& some of the measures are interrelated. For e-ample& if you replace the motor for the chilled water pump with a high$efficiency motor& then the savings reali@ed from installing an ad=usta(le speed drive on the pump will (e somewhat less than shown.

6e recommended five process energy management measures which save a total of /13&),. 567<yr and reduce demand (y .3 56. The energy cost savings is +3*&11.. The local utility offers incentives for installing high$efficiency chillers and motors. The cost to implement these five process improvements& including the utility re(ate& is appro-imately +30&)** for a simple pay(ac' period of eleven months.

A

1. 8eplace chiller	1*&1*0	1)&4**	1.)	1./&)**	0/.4
0. #nsulate molder (arrels	/&.44	0&)0*	*.)	.3&.,)	*
3. !SD for water pump	3&,41	4&1**	1.)	4.&0.4	*
/. 7igh$efficiency motors	1&,/1	.&01.	1.*	131&/11	1..3
). 8educe pea' usage	3&0/.	*	#mmediate	*	/*.1
4. 7igh$efficiency lighting	1&0/4	0&33,	*.3	10/&,11	/4.1
1. T. lightingBB	3&/13	1/&*,1	/.1	).&.),	1).3
.. 8eflectors	/&/*4	4&13*	1.)	41&11*	..0
,. 7igh$efficiency !CBB	1&*34	1&*0)	1.*	11&.4/	0./
1*. !<C controls	.*3	,/)	1.0	11&.0/	*
11. E-tending !<C ducts	.&1**	)&***	1.1	1)*&***	*
10. 2iscellaneous measures	0&1),	0&401	1.1	)1&4.,	*
Totals	+)/&430	+)*&133	*.,	..4&0,.	13.

B #mplementation cost is reduced (y amount of utility re(ate.
BB This E2 8 is shown for information purposes only. #ts values are not included in the totals at the (ottom of the ta(le.

This facility has three identical 4*$ton reciprocating chillers that are at least si- years old and that have a full$load operating efficiency of 1.1. 5 6<ton. ! computer schedules the chillers wee'ly so that during a given wee'& one chiller operates all of the time& one chiller operates under varying loads a(out half of the time& and the third chiller is turned off. Under this system& each chiller operates 31)* hours per year.

6e analy@ed si- alternatives for chiller replacement at this facility. 6e loo'ed at three different types of new chillers 9a standard efficiency reciprocating chiller& a high$efficiency reciprocating chiller& and a screw chiller: and analy@ed the savings for two different scenarios. For the first& we assumed that the facility would not replace a chiller until one of the e-isting chillers failed. For the second& we assumed that the facility would replace one of the e-isting chillers immediately. The energy and cost savings& the implementation cost and simple pay(ac' period& and the demand reduction for each alternative are shown in Ta(le ##. ;ased on our analysis& we recommended that the company should immediately replace one of its e-isting chillers with a new screw$type chiller.

8eplace with standard efficiency chiller					
1. On failure (asis	3&,.*	*	#mmediate	4.&40)	,.0
0. Cow	1&,4*	0*&***	0.)	131&0)*	1../
8eplace with new high$efficiency reciprocating chiller					
3. On failure (asis	/&.)*	0&***	*./	.3&40)	10.)
/. Cow	,&1**	00&***	0.3	141&0)*	00.3
8eplace with new screw chiller					
). On failure (asis	)&3)1	*	#mmediate	,0&0)*	10.3
4. Cow	1*&1*0	1)&4**	1.)	1./&)**	0/.4

#n=ection molding machine heater (ands are used to preheat the (arrel and maintain the correct operating temperature of in=ection molding machines. 7owever& unless the heater (ands are insulated& they lose significant heat to the surrounding air. This heat loss creates an additional cooling load for the air$conditioning system. 8ecent studies have shown an energy savings up to /* percent 9not including air$conditioning savings: when an insulating (lan'et is used.[0]

6e analy@ed the use of insulation (lan'ets for the in=ection molding machines at this facility and determined that the insulating (lan'ets would (e feasi(le for use on five of the machines. 6e calculated the total annual energy savings for each machine as the sum of the savings associated with reduced heat loss from the (arrel surface 911&,.) 5 6 7<yr: and the savings associated with reduced air$conditioning load 9/&1,/ 5 6 7<yr:. The total energy savings for insulating five machines was .3&.,) 5 6 7<yr and the energy cost savings was +/&.44<yr.

6e recommended purchasing (lan'ets with straps for easy installation and removal. The (lan'ets cost a(out +110 per 1** tons of machine capacity. For five /)*$ton machines& the implementation cost would (e +0&)0*. This E 2 8 has a simple pay(ac' period of 4 months& ma'ing it a highly cost$ effective recommendation.

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[2] DUpgrading #n=ection 2olding 2achines for #mproved Efficiency&D Center for 2aterials Fa(rication& E>8# Tech<!pplication& ?ol.4& Co.1& 1,,0.

This facility uses chilled water to cool the in=ection molding machines. The pump that supplies this process water has a 3*$horsepower motor. #nstalling ad=usta(le speed drives 9or varia(le speed controls: on centrifugal pump motors can (e very cost effective. The conventional practice for controlling such pumps is to run the motor at full speed and control the flowrate with a valve. Under this practice& the motor consumes the same amount of energy regardless of the amount of water that is (eing moved. This is li'e controlling the speed of a car with the (ra'e while 'eeping the accelerator pushed all the way to the floor. 6ith an ad=usta(le speed drive& the system flowrate can (e varied (y controlling the speed of the motor. Energy is saved (ecause the motor consumes significantly less power.

The power re%uired (y a centrifugal pump motor increases with the cu(e of its speed. For e-ample& when a pump s speed is dou(led& the power re%uired increases (y eightfold 90^{3}:E similarly& cutting the speed in half decreases the power re%uirement (y a factor of eight. ;ecause the flow rate of a centrifugal pump is directly proportional to the speed of the pump& the power re%uired (y the motor is proportional to the cu(e of the flow rate. Therefore& using the motor speed to directly control the

The operating efficiency of electric motors has improved in recent years. Depending on the horsepower rating& the operating efficiency of high$efficiency motors can (e from 1$1* percent higher than the operating efficiencies of standard motors. 6e inventoried the motors at this facility and determined that it would (e cost$effective to replace 0) of the 4) motors with high$efficiency motors as the e-isting motors failed. For very small motors or seldom$used motors& the simple pay(ac' period is too high to ma'e replacement cost$effective.

The total energy savings for this E28 is 131&/11 567<yr with an energy cost savings of +1&,/1. The implementation cost for each motor was reduced (y the applica(le utility re(ate. The total implementation cost is +.&01.& and the overall simple pay(ac' for this E28 is 1 year. Ta(le #? shows the savings analysis for the motors (y horsepower.

7orsepower	Cum(er of motors	2otor Efficiency		Energy Savings 9567<yr:	Energy Cost Savings 9+<yr:	#mplementation Cost 9including re(ate:	Simple >ay(ac' >eriod
		Standard	7igh				
)	4	..3,	..,*	)&.*.	331	11/	*.)
0*	3	...4	.,03	1*&,/,	43)	31.	*.4
3*	/	.,*1	.,31	10&*3.	44,	1)0	1.1
/*	1	.,*.	.,3/	/&,31	0.4	0.4	1.*
1)	11	.,11	.,//	1*3&4,1	4&*1/	4&4..	1.1
				131&/11	1&,/1	.&01.	1.*

6e analy@ed the e%uipment use at this facility to determine which e%uipment could (e limited to use during off$pea' hours. ! ma=or savings would (e reali@ed if the company restricted monthly testing of its emergency fire pump to off$pea' hours. The fire pump has 1)*$hp motor with a motor efficiency of ,3F. 6e assumed that during a monthly test the pump would run for) minutes during a pea'$demand window of 1) minutes. Under those conditions& the power consumption of the motor was calculated as /*.1 56. Shifting this use to off$pea' times would provide an annual demand charge savings of +3&0/.<yr. ;ecause the company operates three shifts& testing the fire pump off$pea' would (e feasi(le.

 6 e surveyed the lighting in the facility and recommended replacement of standard efficiency lamps with high$efficiency lamps. Ta(le ? shows the type and num(er of each type of lamp in the facility& and shows the annual energy use and cost savings that will (e reali@ed when all of the lamps of each type have (een replaced with high$efficiency lamps.

1&*41	CF/*	10.&134	1&/41	7F3/	1,&31*	1&10*
.0	CF1)	/4&4/*	0&1*)	7F4*	,&30.	)/0
1,	#G1**	/&,/*	0.1	C 2 F01	3&4*4	0*,
13	#G1)	1&313	/0/	C 2 F13	4&*/)	3)1
11,	2 ?/**	/1*&))*	03&.10	7 2 ?30)	.4&40.	)&*0/
		),.&11,	3/&4,)		10/&,11	1&0/4

The energy savings from high$efficiency lighting also includes a savings of 0&0** 5 6 7<yr due to the reduced heat load on the air$conditioning system. Therefore& the total energy savings for this E 2 8 is 101&114 5 6 7<yr and the cost savings is +1&313.

#n most cases& we recommend replacement of lamps on a failure (asis 9spot relamping: (ecause the pay(ac' period is much longer with a group relamping program. Ta(le ?# shows the costs and pay(ac' for (oth methods (ecause the local utility will only pay a re(ate for replacement through a group relamping program.

 6 e also analy@ed replacing the CF/* lamps with T$. lamps.   ;ecause replacement with T$.s re%uires a new fi-ture& group relamping is the only feasi(le implementation method for this lamp. #n addition& the local utility pays a higher re(ate for relamping with T$. lamps (ecause the change is more permanent than relamping with 7F3/ lamps. Ta(le ?## compares the three alternatives for replacement of CF/* lamps.

	)3/	*.)	1&3)4	1.3
	.0	*.0	)*1	*.,
	1&1,*	*.3	/&133	1.1
	0.4	*..	01)	*..
	0/1	1.0	00.	1.1
	0&33,	*./	1&*,,	1.1

7F3/ 9spot:	0)&0/.	1&/4/	4.,	)3/	*./
7F3/ 9group:BB	0)&0/.	1&/4/	4.,	1&3)4	*.,
T. 9group:BB	).&.),	3&/13	1).3	1/&*,1	/.1

B #ncluding savings from reduced air conditioning load.
BB The implementation cost is reduced (y the applica(le utility re(ate.

Choosing the appropriate alternative for CF/* replacement involves a num(er of factors. !lthough the pay(ac' for the T.s is longer& this alternative includes new (allasts and new fi-tures& meaning that (allasts and fi-tures will not need replacing anytime soon. Other factors that must (e considered include lamplife and (allast life.

The lamp lifes of the T.s and the 7F3/s are e%ual 90.41 years for the office area and 1.4, years for the production floor. Therefore group relamping with T. lamps& with a simple pay(ac' period of /.1 years does not appear to (e cost effective in the office areas (ecause the T.s would need to (e replaced 9in 0.41 years: (efore they had paid for themselves. #n the office areas& therefore& 7F3/s with a pay(ac' period of *., years seem to (e a (etter group relamping choice. #n the production area however& (oth 7F3/s and T.s would last long enough 91.1 years: for their implementation costs to (e fully reali@ed.

Since T.s present significantly higher annual savings they might (e a (etter group relamping choice in the production area. 7owever& there are 1&*0) CF/*s in the office area and only /0 in the production area. Therefore& we recommended replacing the CF/* lamps with 7F3/s.

8eflectors are availa(le for fluorescent lamp fi-tures which increase the light output of the fi-ture. 6hen the reflector is installed in a four$lamp fi-ture& two of the lamps 9and one of the (allasts: can (e disconnected without decreasing the light level significantly. #n this facility& we recommended installing 0/) reflectors in the office areas (ecause the offices were overlighted. The lighting level in the offices was (etween ,* and 10* footcandlesE the recommended level for office wor' is)* to 1) footcandles.

The energy and demand savings from installing reflectors results from disconnecting lights and (allasts. This facility had a total of ,.* CF/* lamps and /,* (allasts. 7owever& we calculated the energy savings using 7F3/ lamps instead of CF/* lamps& assuming the facility would implement our recommendation to install the higher efficiency lamps. The energy savings of 41&11* 5 6 7<yr includes a savings on reduced air$conditioning load of 1/&,., 5 6 7<yr. The total cost savings of +/&/*4 includes an energy cost savings of +3&).3<yr as well as an e%uipment cost savings of +.03<yr as a result of having only half as many (allasts and lamps to replace each year. 9Cote that this is a conservative estimate (ecause it does not include a la(or cost savings on replacing e%uipment.:

The cost of purchasing and installing the reflectors and disconnecting the lamps and (allasts was estimated at +3/ per reflector& for a total cost of +.&33*. The local utility offers a re(ate for installing reflectors of +.* per 5 6 reduced. ;ecause this E2 8 reduces the demand (y 0* 5 6& the re(ate will (e +1&4**E therefore& the total cost of implementation will (e +4&13*. This gives a simple pay(ac' period for this E2 8 of 1.) years.

This facility has currently 1.* tons of central air$conditioningA 10) tons are high$efficiency units and)) tons are low efficiency units. There are three)$ton and four 1*$ton low$efficiency units with an SEE8<EE8 of ..1E they are a(out si- years old. 6e analy@ed the energy and cost savings for replacing the)$ton units with units with a SEE8 of 10& and the 1*$ton units with an EE8 of 1*. 6e did not recommend immediate replacement& (ut only when a unit fails. Since an air$conditioning unit typically lasts 10 to 1) years& this recommendation will only (e implemented if one or more of the units fails une-pectedly.

6e analy@ed the savings potential for a)$ton unit and a 1*$ton unit to show the company its options if one of the units fails. 6e did not include this savings in our overall savings chart (ecause of its uncertainty. The savings and cost summary are shown in Ta(le ?##.

Si@e of !C Unit 9tons:	)	1*
SEE8<EE8	10.*	1*.*

Energy Savings	3&1,3	3).4
Cost Savings	00*	0*.
Cost >remium	/)*	1)*
Utility 8e(ate	31)	))*
Simple >ay(ac' >eriod	*.3/	*.,4

The office area of this facility is air$conditioned (y nine rooftop units. ! lthough the offices are only occupied from .A** to 4A**& five days a wee'& the air conditioning units operate 0/ hours a day. 6e recommended installing timers on the air conditioning units that would turn them on one hour (efore the start of normal wor'ing hours and turn them off when the offices closed. ! manual override feature would allow air conditioning of offices when they were used at other times. Ta(le #H shows the summary of energy and cost savings from installation of the timers.

3	)	..1	/&*/0	1.0
0	)	1*.*	0&3/)	1*4
/	1*	..1	11&/31	)1)
			11&.0/	.*3

The ceiling in the production area of the facility is /* feet high. The air conditioning supply and return ducts are located in the ceiling. ;ecause hot air rises& the cold air will mi- with hot air (efore it reaches the plant floor. 6e recommended lowering the supply and return ducts to 0* feet to decrease the energy used (y the air conditioners. Gowering the supply ducts means that colder air will reach the plant floor& so less cold air will (e needed. Gowering the return ducts means that cooler air will (e returned to the air conditioning units& thus improving their efficiency.

6e analy@ed the cooling load for the plant floor using the DOE$0 program. The current energy consumption for air conditioning the plant floor is appro-imately)**&.** 5 6 7<yr at a cost of a(out +0,&***<yr. 6hen the ducts were dropped to 0* feet& the simulation showed an energy consumption of appro-imately 3)*&4** 5 6 7<yr with a cost of +0*&3**<yr. Thus& the annual energy savings would (e a(out 1)*&*** 5 6 7 with an annual cost savings of +.&1**. 6e estimated an implementation cost of +)&*** which gives a simple pay(ac' period of 1.1 years.

We also recommended several other measures that could save small amounts of energy at this facility. These included installing occupancy sensors to turn off lights in areas that were often unoccupied, replacing incandescent lamps in the exit signs with LED units, and installing electronic variable-voltage controls on the constant speed motors on the plastic regrinders which frequently stand idle. The dollar savings for the occupancy sensors and the motor controls were calculated using the off-peak cost of electricity because neither of these measures guarantees a demand reduction during peak hours.

1. Occupancy sensors	1&**.	10.	*.1	00&/*0	*
0. GED e-it ssipBiDEl(.GED 10.	*.1 hGò GED e	H3gò.il e3-it 8 Paas.	ru1gvi® 1.		