ENERGY EFFICIENCY – THE 5TH FUEL

- AT HOME AND IN THE WORK PLACE.

FINAL REPORT

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ABSTRACT

Energy efficiency is considered the 5th fuel after coal, petroleum, nuclear, and alternative energy. Appliance efficiency in the home as well as motor and pump applications in the workplace can yield financial returns that exceed those of the famous investor Warren Buffett. Energy efficiency is often overlooked because of lack of understanding and let's face it, it's not sexy, or flashy. However, energy efficiency has the ability to allow us to exceed the carbon emission goals of the Paris Climate accord. All we need do is make use of existing technology and consider rate of return.

Your air conditioner is the largest consumer of energy in the typical Florida home amounting to 50% to 70% of your annual bill. Does your monthly bill always peak in the summer months? This paper will lay out the steps you can take to calculate an attractive rate of return.

Pumping equipment and it associated electricity consumption comprise the majority of the energy cost in the phosphate industry. A pro-forma cost-based computer model was developed to determine the savings associated with pump, motor, and power factor correction using a typical 100 hp motor. Rates of return of 37%, 42% and over 100% are typical of the improvements that await discovery by the process engineer.

ACKNOWLEDGMENTS

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Many thanks go to Gary Albarelli, Karen Stewart, and Malysavanh Birdy of the Florida Industrial and Phosphate Research Institute who were gracious and hospitable during my five days of "camping out" in their library.

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Much gratitude goes to Mark Thompson and Terry Tarte who in 2004 encouraged me to pursue the "hobby" of providing continuing education to professional engineers. That part-time hobby has now become my fulltime work in my new company Green Energy Engineering.
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Author's note – The first edition of this paper appeared in the January 2018 issue of the Florida Engineering Society (FES) "Energy" magazine on page 13. The author is thankful to FES for permission to include the second edition (with some clarifying edits) on the Green Energy Engineering www.GEEINTL.com website. If the reader is interested in obtaining answers to their specific home, but does not want to perform all the calculations shown below, they can forward the raw electric billing data and a $20 check (made payable to Green Engineering Inc.,) to Eric Coffin 4737 Dolphin Cay Lane South Unit #B108, St. Petersburg, Florida 33711-4671. The author will then perform the analysis and provide the homeowner with a report outlining the financial options of air conditioning replacement. This is now the third edition and has been expanded for the AIChE Clearwater Phosphate Conference. This paper includes energy efficiency in the workplace by reviewing the monetary savings from improving motor efficiency, improving pump efficiency, and improving the electrical power factor.

Introduction

First came coal, then petroleum, then nuclear, and then alternative energy; such as wind and solar. The new kid on the block is the (5th fuel[1]) which is downstream of the electric utility and is called energy efficiency[2]. This is a large and mostly untapped method of reducing greenhouse gases, by considering the life cycle cost of energy consuming equipment and applying existing energy-efficient technologies. While the initial upfront capital cost of more efficient equipment may be higher, this is more than made up for in reduced reoccurring monthly fuel cost. In other words it has a great rate of return.

Consider the traveling salesperson who puts 300 miles on their car each week and buys $4 per gallon gasoline. By trading in that 13 mpg for a new 35 mpg they could save over $3,000 per year. Air conditioners also have a "mpg" and it is called Energy Efficiency Ratio (EER) and is defined as BTU per hour of enjoyed cooling divided by watts of electricity painfully purchased at an outside temperature of 95ºF. This paper will show how you, the payer of electric bills, can make an informed a/c purchasing decision that will yield a better rate of return than enjoyed by the famous investor Warren Buffett.

The motors and pumps in a phosphate plant account for the majority of the electric load and cost of operation. Many times the process changes and/or new equipment is available and those pumps and motors are costing the company extra electricity cost. As will be shown in this paper some efficiency improvements payback in less than one year and are available with today's technology.

[1] The 5th Fuel term was first coined by American physicist Amory Lovins in the mid-1980s . Dr. Lovins is co-founder, chairman, and chief scientist of the Rocky Mountain Institute an independent, entrepreneurial, nonprofit think-and-do tank that implements transformational energy and resource efficiency, chiefly in the private sector.

[2] The term "Energy Efficiency Gap" was first coined by Eric Hirst and Marilny Brown in their 1990 paper "Closing the efficiency gap: barriers to the efficient use of energy." Dr. Brown is a professor in the School of Public Policy at Georgia Tech and her research papers can be found https://spp.gatech.edu/people/person/91044ab3-9e96-5940-80a3-46f80924f3d1

Efficiency stories

According to the July 7, 2008 issue of *Forbes Magazine*, "The Case for Efficiency" there was a 46% drop in U.S. energy intensity between 1975 and 2005 that did not come from giant plants but instead "zillions of tiny pieces imperceptible to the untrained eye,………. energy efficiency gets little respect."

A similar story comes from the January 17, 2015 issue of *The Economist* magazine entitled "Invisible Fuel." Eleven members of the International Energy Agency, including U.S. and European countries, saved 1.4 billion tonnes of oil in 2011, worth $753 billion. They go on to say "The cheapest and cleanest energy choice of all is not to waste it."

A 2010 McKinsey & Company report entitled "Energy efficiency: A compelling global resource" states that "Globally, energy efficiency represents about 40% of the greenhouse gas reduction potential that can be realized at a cost of less than €60 per metric ton of carbon dioxide equivalent. In many cases, it is an extremely attractive upfront investment that pays for itself over time…"

According to the 2012 United Nations Environment Programme – Sustainable Buildings and Climate Initiative – "Globally buildings account for approximately 40% of annual energy consumption and up to 30% of all energy-related greenhouse gas (GHG) emissions…… The building sector has also been shown to provide the greatest potential for delivering significant cuts in emissions, at the least cost……" I think they are saying low hanging fruit.

"Energy Efficiency 2017" published by the International Energy Agency points out that "primary energy demand needed to produce one unit of gross domestic product (GDP) – fell by 1.8% in 2016….In 2016 the world would have used 12% more energy had it not been for energy efficiency improvements since 2000…….energy efficiency is also bolstering energy security. Japan, for example, oil imports would have been 20% higher in 2016 and gas imports 23% higher had those efficiency gains not been achieved…..In Germany and the United Kingdom, Europe's largest gas markets, energy efficiency improvements resulted in gas savings equivalent to 30% of Europe's total imports from Russia.

In the January 2017 Electricity Markets & Policy Group – Technical Brief – Lawrence Berkeley National Laboratory pointed out that "States and utilities increasingly rely on energy efficiency as a resource as a means of managing utility costs (e.g., potentially deferring generation capacity and possibly distribution system facility investments, and avoiding fuel costs), lowering consumer bills, and reducing emissions."

"The Global Risks Report 2018 – 13th Edition published[3] by the World Economic Forum points out that extreme weather events have the highest likelihood of occurrence and also the largest global impact. The following figure 1 comes from page 3 of that report and the green diamond in the upper right corner represent extreme weather events.

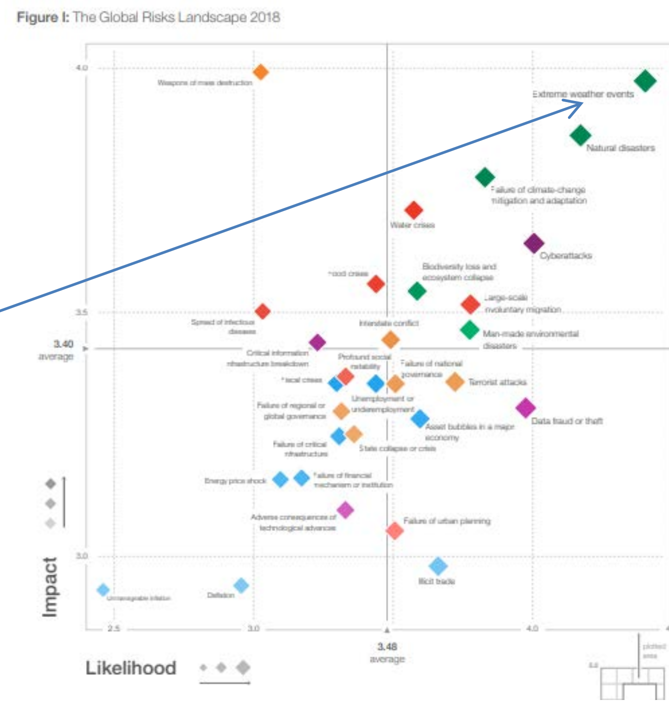


Figure 1

As is always the case; things are interconnected and as you can see from this figure 2 from the same report "changing climate" is the largest arrow head in the circle of connectedness. Some of those connections include; water crises, large-scale involuntary migration, food crises, biodiversity loss and ecosystem collapse.

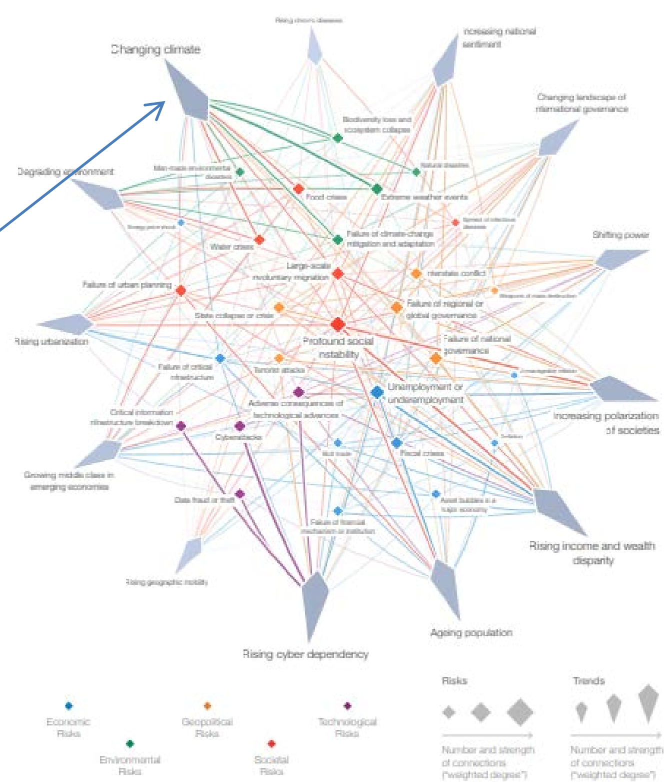


Figure 2

[3] The Global Risk Report 2018 is available athttp://www3.weforum.org/docs/WEF_GRR18_Report.pdf

Residential Air Conditioner

You also can be one of those "zillions of tiny pieces" by looking around your home or business for those items that consume electricity. While doing so remember the Pareto[4] principle also known as the 80/20 rule that states in part 80% of the electricity is consumed by 20% of the appliances. With that as a backdrop did you know that your air conditioner is the largest consumer of electricity in your home accounting for approximately[5] 65% of your annual electric bill. In this paper we will lay out the steps to determine if that old a/c should be replaced with an energy efficient unit. By doing so you may be able to save money, obtain a great investment, and reduce your carbon footprint.

Photo 1

Step one is to collect 12 or more months of your electric bills. You may have saved the paper bill or you may need to go online to your local utility and retrieve them from your online account. Take note of the total kWh consumption and enter the values into a spreadsheet. Ensure that you are looking at the total kWh and not just the first step of what may be a tiered bill. Also enter the total monies paid and you will notice that there are a host of charges including customer charge, demand, energy, conservation cost recover, taxes, fees, etc. Table 1 to the right is an example of my bills and yours should look similar. You can also divide the monthly money by the kWh to obtain the overall $/kWh which will be higher than the listed electric tariff due to all the add-on taxes.

Month	kWh	$
Jan	2,319	$373.72
Feb	1,757	$278.96
Mar	1,552	$244.40
Apr	2,529	$366.31
May	3,312	$485.07
Jun	4,353	$642.97
Jul	4,830	$715.32
Aug	5,264	$781.15
Sep	5,586	$829.99
Oct	4,741	$701.82
Nov	1,981	$283.19
Dec	2,201	$316.56
TOTALS	40,425	$6,019.46

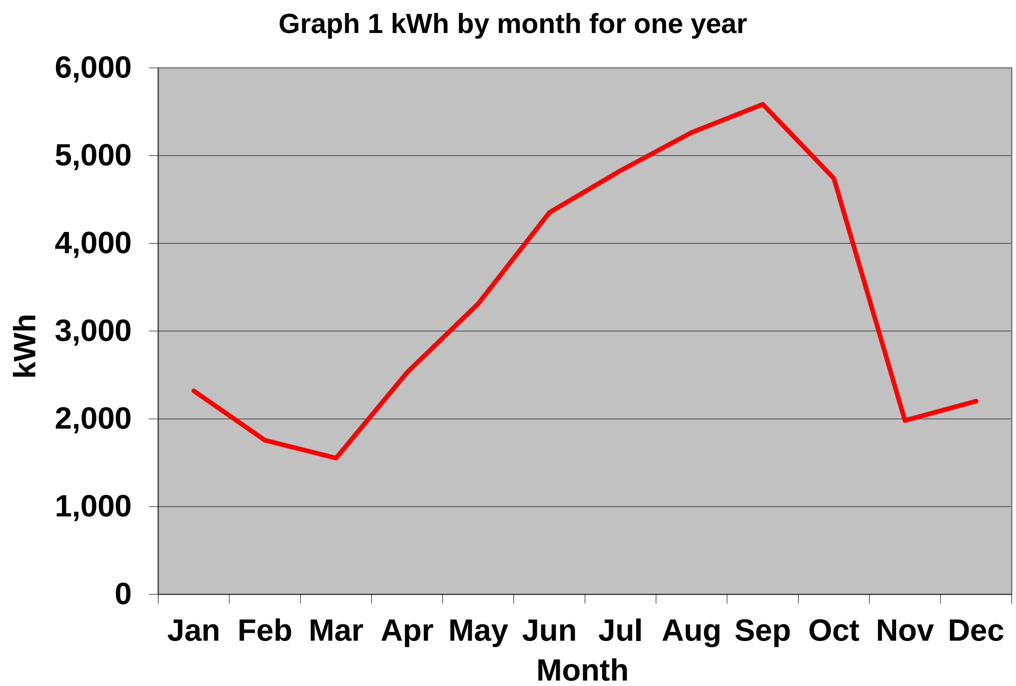
Tabulate your annual electric bills

Table 1

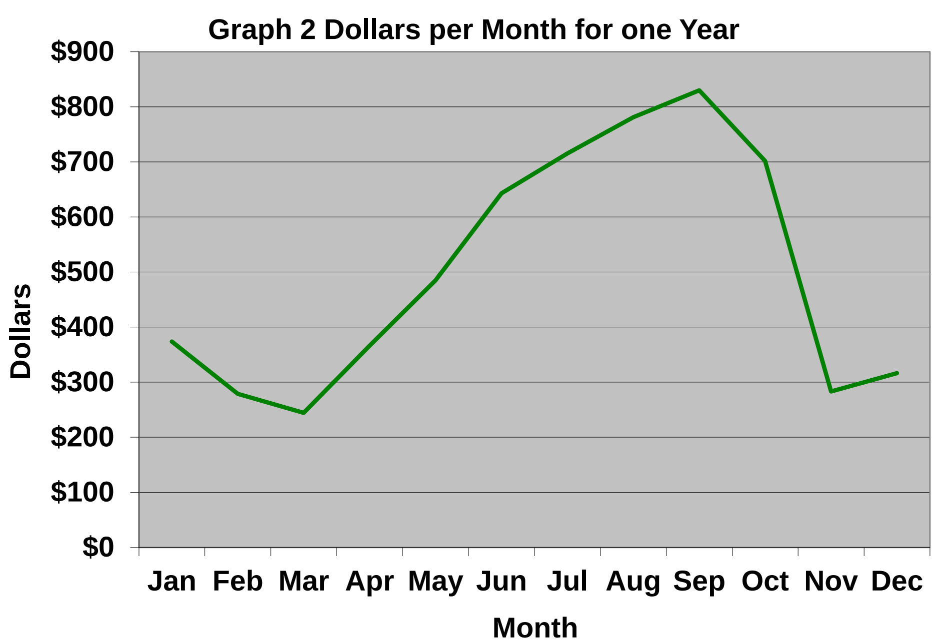
[4] In 1896 Italian economist Vilfredo Pareto, while walking through the countryside noticed, and later proved; that approximately 80% of the farmland was owned by 20% of the population.

[5] See http://michaelbluejay.com/electricity/howmuch.html for a breakdown of appliance usage.

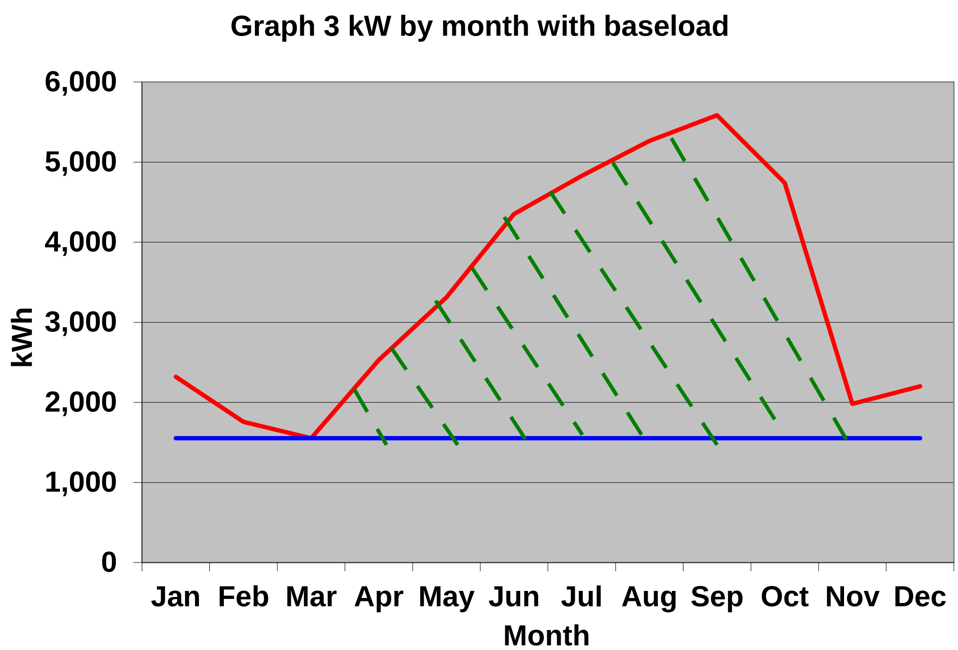
Step two is to plot the data. Plot the kWh by month and you should have a kWh curve that looks like graph 1.



Also plot the dollar curve as shown in graph 2. We all know that the summer bill is quite large and this graphically shows the summer peak



Step three is to choose the minimum value and draw a straight blue line across the bottom of the graph. You should have a graph that looks similar to chart 3. The assumption here is that March is a mild month with no heating or air conditioning. This base load is the usage under the blue line and is comprised of water heater, dishwasher, refrigerator, lights, washer and dryer, etc. Note the green shaded area. This represents the a/c portion of your annual electric bill. Recall that there are 8,760 hours in one year (24*365). According to the American Society of Heating, Refrigeration and Air Conditioning Engineer (ASHRAE) "Fundamentals Handbook" the typical Florida home will require 4,000 to 6,000 hours of air conditioning and maybe 200 hours of space heating. In Chicago (the windy city) those numbers would be reversed. The very low Florida space heating need can be seen in the low values for Jan, Feb, and Dec. This just proves how mild our winters are and why we are the snow bird state.



Step four is to read your air conditioner name plate (see photo to right) and find the tonnage of the unit such as 3 tons or 36,000 BTU per hour. Also find the mpg or in this case the EER or SEER rating. EER is known as the energy efficiency rating and has been around for many years.

$$EER = \frac{BTU\_per\_Hour\_of\_cooling}{Watts\_of\_Electric\_Purchased}$$

At a constant outdoor condenser temperature of 95°F

Photo 2

SEER, or Seasonal Energy Efficiency Rating, is similar except it uses a range of various temperatures for the outdoor condenser that make up a cooling season. One can convert between the two as follows EER = 0.875 * SEER (note this is an approximation). SEER was invented by a/c manufactures to increase the efficiency number by running the air conditioner in cooler climates. Think of this equation $Q = \dot{m} * Cp * \Delta T$ The wider the delta T the larger the heat flow Q becomes. In Florida the Freon in the condenser might be 120 ºF and the outside temperature might be 95 ºF providing a 35 º Δ T; therefore the current draw of the compressor motor would be quite high. If the outdoor temperature is 35 ºF the Δ T becomes 85 and the motor current draw is much lower; thereby saving electricity and yielding a great SEER number.

Step five is to add together the kWh identified by the green hash marks under the kWh curve by subtracting the constant base load (represented by the blue line) from the actual peak load (represented by the red line). Only add together the cooling season. This will yield the kWh consumed in the a/c season which in this case is 19,751 kWh or 19,751,000 watt hours. Some calculations are required to uncover some important information.

The wattage draw of this 3 ton example a/c unit is
= (12,000 BTU/ton * 3 tons) / (8 BTU/hour / watt) = 4,500 watts.

The actual hours of a/c use is
= 19,751,000 watt hours / 4,500 watts = 4,389 hours.
I work and use a set-back thermostat to avoid paying for air conditioning during the day. Otherwise the hours calculated here would be much larger i.e. 5,000 or 6,000 hours.

The dollars for operating this example a/c unit is
= 19,751 kWh * $0.1612 $/kWh = $3,183.

The annual carbon footprint in pounds of CO_2
= 40,425 kWh * 1.35 #/year of CO_2/kWh = 54,574 pounds of CO_2 annually

Step six is to obtain bids and EER ratings on new units and calculate your new operating cost. This example is for a 3 ton unit with an EER of 14.

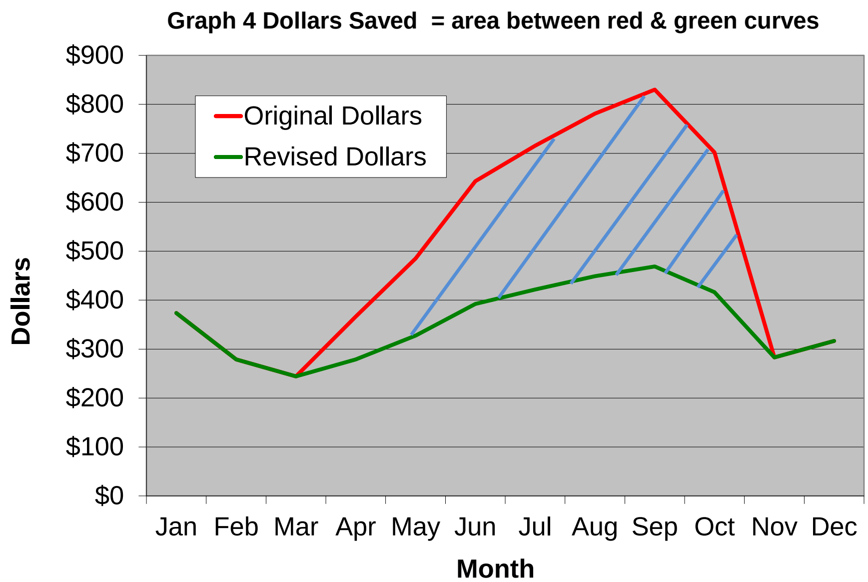
The new wattage draw is
= (12,000 BTU/ton * 3 tons) / (14 BTU/hour / watt) = 2,571 watts.

The new a/c consumption is
= 2,571 watts / 1,000 watts / kW * 4,389 hours = 11,284 kWh.

The new operating cost is
= (2,571 watts/1000 watts/kW) * 4,389 hours * $0.1612/kWh = $1,819

Dollar savings of new a/c
The savings are
= $3,183 - $1,819 = $1,364 per year.

These savings are represented by the blue shaded area that is seen in Graph 4 to the right. The red line is the original month-by-month electric bill and the green line represents the new reduced cost associated with a new energy efficient air conditioner. The high summer bills have been reduced and those are the savings that help pay for the new unit. Also notice that the winter heating is still the same as before as the assumption is that space heating is done with electric heat strips. If you purchase a heat pump rather than the straight cool machine represented here, you can expect to enjoy lower winter heating bills. This graph represents just one year of savings, but in reality these savings will continue for ten or more years and more then repay the owner for the new purchase price.



The original annual kWh consumption was 40,425.
The new consumption is
= 40,425 total – 19,751 old a/c + 11,284 new a/c = 31,958 kWh.

The new carbon footprint is
= 31,958 kWh * 1.35 #/year of CO2/kWh = 43,143 pounds of CO2/y.

This yields a carbon footprint savings of
= 54,574 – 43,143 = 11,431 pounds of CO2 annually.

Step seven is to obtain bids and construct a table as follows with the bid price and the new calculated cost and annual savings. Note that the EER of 14 has an annual savings of $1,364 (this will be used below).

Table 2 - Bids and new operating data							
New Installed Cost	$0	$2,000	$2,200	$2,400	$2,600	$2,800	$3,000
EER	8	9	10	11	12	13	14
Watts	4,500	4,000	3,600	3,273	3,000	2,769	2,571
a/c Operational Cost	$3,183	$2,829	$2,546	$2,315	$2,122	$1,959	$1,819
Savings from Existing	$0	$354	$637	$868	$1,061	$1,224	$1,364

The above calculations can be input to a spreadsheet and before and after dollar curves can be created for the year, such as shown in Graph 4. The area between the red and green curve represents the dollars saved by installing a more efficient a/c unit. These savings are the 5th fuel, aka energy efficiency that was introduced in the beginning. The homeowner enjoys the dollar savings and the electric utility burns less fuel. AND less greenhouse gas emissions!

Step eight is to determine the rate of return on this investment. This can be done by using the uniform series present worth equation shown here.

Figure 3

$$P = A\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right]$$

Where A = annual savings
P = the total installed cost (note this is the unknown we are seeking)
N = the number of years
i = the interest rate

If you program this uniform series present worth equation into your spreadsheet (or you can use your HP financial calculator) you can work backwards towards your allowed total installed cost, or P, in the above equation. For instance, using the annual savings calculated above, a ten-year life, and a desired 10% return on investment….one could spend up to $8,381 on a new EER 14 a/c unit.

Table 3 10% Return				
P	A	*i*	n	Factor
$8,381	$1,364	10.0%	10	6.14

If, however, you wanted a 15% return on your money…one could spend up to $6,845.

Table 4 15% Return				
P	A	*i*	n	Factor
$6,846	$1,364	15.0%	10	5.02

If you were Warren Buffett and would only accept 20% on your hard-earned cash…one could spend up to $5,718.

Table 5 20% Return				
P	A	*i*	n	Factor
$5,719	$1,364	20.0%	10	4.19

By calculating different EER values you can create different annual savings and arrive at different total installed costs. Use this family of savings data to select the best bid and I would suggest at least three bids, (and more are better). The bids should include items such as: equipment, installation, permits, removal and proper disposal of old unit, Freon, and start-up, a new air handler, duct work upgrades, thermostat, electrical wiring, circuit breaker, etc. Depending on the age of you're a/c it may be that the unit is still using the old R22 Freon that is being phased out in favor of the new R410a refrigerant.

Compare the details of the bids to ensure that you are comparing apples to apples. Some contractors will only quote equipment and a/c installation and ignore any electrical wire cost so as to avoid a high bid, and also to avoid running new wires through walls and attic – if new wiring is required to accommodate new larger heat strips. Some a/c contractors are not comfortable with 240 volt wiring and may suggest you hire a licensed electrician. Once you have all this information you can make a very good financial decision.

As a final note be sure you are dealing with a properly trained and licensed a/c or electrical contractor. Contact your friends and neighbors and seek their advice on contractor performance. Also check with the county licensing board to confirm they are licensed and insured.

Summary of Savings

This table 3 is a summary of the before and after results of upgrading to a more energy efficient EER14 air conditioner using our typical 3 ton unit. As you can see from this summary there are impressive savings across the board and the percent savings indicate the power of the 5th fuel. For those of us in the power plant business we know that increasing boiler / steam turbine efficiency is hard, expensive and yields results of less than 1%. With this a/c example we see saving of 21% to 43% depending on the variable under consideration.

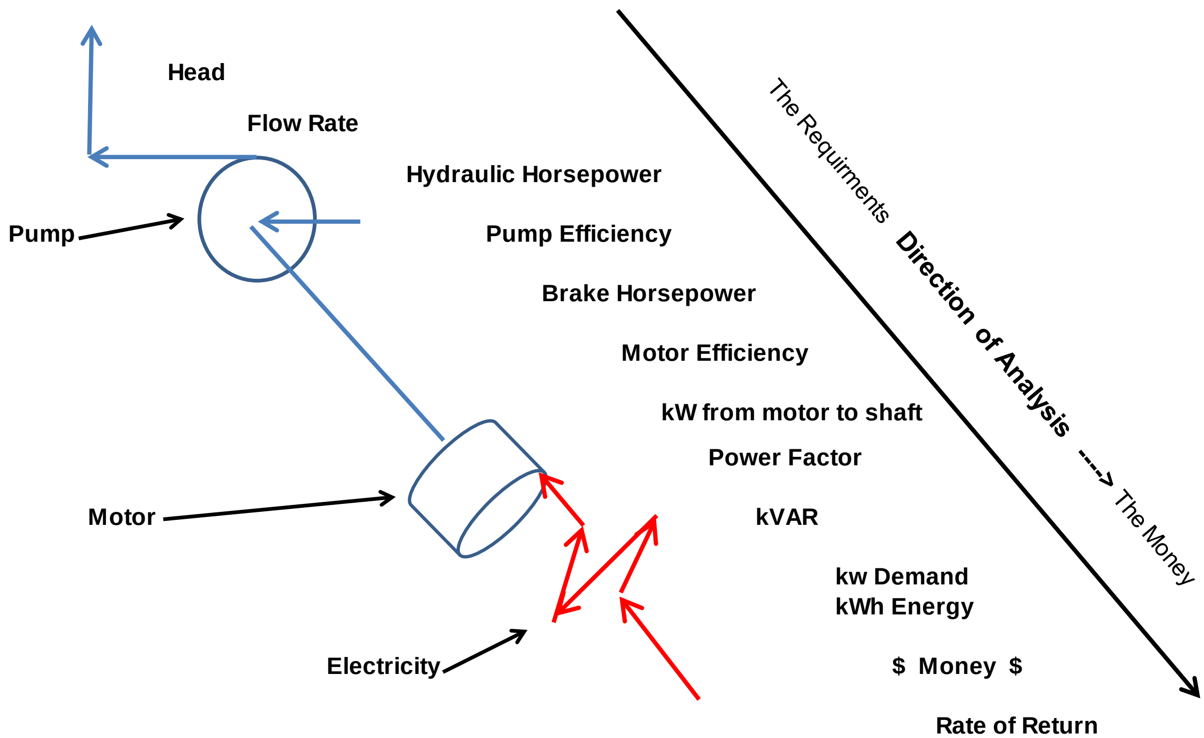
Table 6 Summary of Savings before and after				
Variable under consideration	Existing Condition	New a/c Installed	Total Savings	Percent Savings
Total annual kWh used	40,425	31,958	8,467	21%
Annual $ dollars	$6,019	$4,428	1,591	26%
EER	8	14		
Watts used in a/c	4,500	2,571	1,929	43%
kWh used in a/c	19,751	11,284	8,467	43%
Annual $ of a/c	$3,183	$1,819	1,364	43%
A/C as percentage of bill	53%	41%	12%	22%
# CO2/Yr	54,574	43,143	11,431	21%

To recap from the introduction, we have seen that energy efficiency is the 5th fuel as it allows for considerable reduction in the burning of oil, coal, natural gas, etc. Air conditioning is a very well-known technology and efficiency improvements are introduced each year as the government requires ever better energy STAR ratings. We have shown that the higher initial capital cost pays a better return than your bank without the risk of a stock market fall and this short paper is easy to read compared to the hundreds of annual reports that Warren Buffett reads looking for value. This air conditioner evaluation process has allowed you, the homeowner, some insight into just what a great investment you have outside your home in those bushes.

Process Plants

Motors are the largest consumer of electricity in a process plant. This includes motor driven equipment and motor driven pumps. As the air conditioning example above showed there are significant savings to be had with energy efficiency improvements. This section of the paper will now explore the savings from motor efficiency, pump efficiency, and power factor correction. Figure 1 below lays out the method of analysis that was used to come up with the rate of return for various energy efficiency improvements. A spreadsheet model was developed that incorporated each of these steps and the examples given below focus on a 100 hp motor. The electric costs were calculated by a straight $0.09 per kWh and also using the detailed Tampa Electric Company (TECO) General Service Demand (GSD) tariff.

Figure 4 Pump System Analysis

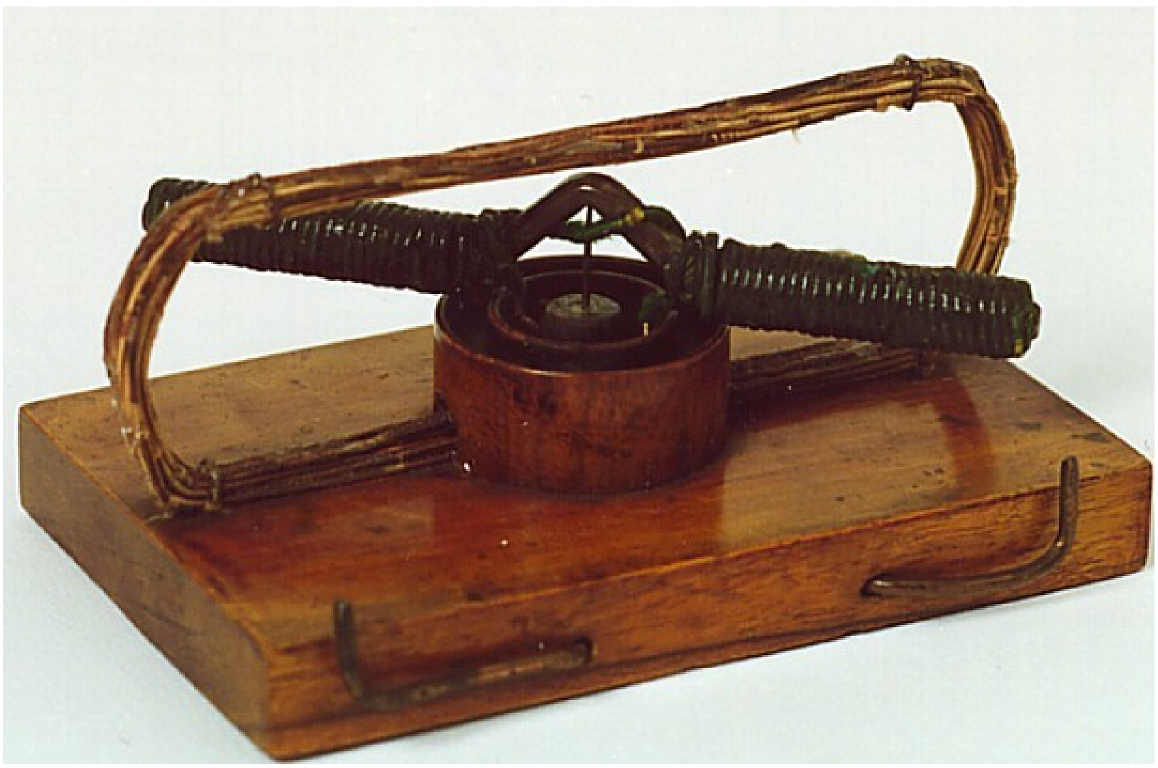


In a pumping system what is desired is flow (1,500 gpm) and head (100 feet) which is measured in hydraulic horsepower (38 hp). But, in order to get the required flow a chain of equipment and associated inefficiencies (75% pump, 90% motor, 85% PF) join hands in ever increasing cost which results in a purchase of 66 hp. In other words 43% of the purchased power is lost to inefficiencies. If the string of equipment were changed to (85% pump, 95% motor, 95% PF) the purchased horsepower would be reduced by 25% to 49 hp and the overall loss would be 23%. The electric savings for this one 50 hp motor would be $9,300 per year. Applied to pumps and motors across the process plant the savings are huge.

Electric Motors

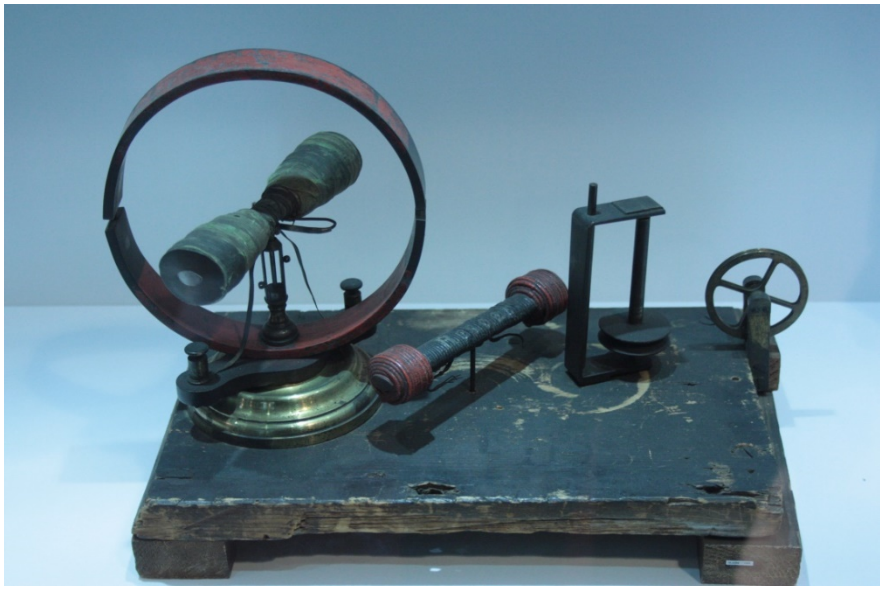
Motors have come a long way in the past two hundred years.
According to Wikipedia..”
https://en.wikipedia.org/wiki/Electric_motor
Electrostatic devices were created by Scottish monk Andrew Gordon in the 1740s
Electric current and the magnetic fields were discovery by Andre-Marie Ampere in 1820
Mechanical / magnetic fields were demonstrated by English scientist Michael Faraday in 1821
Hungarian physicist Anyos Jekik started experimenting with electromagnetic coils and developed the first commutator, stator, and rotor in 1827 as see in this picture below.

Photo 3



This is a photo of an electric motor presented to William Thomson, 1st Baron Kelvin (the Kelvin temperature scale is named in his honor) by James Prescott Joule (the unit of energy the joule is named in his honor. This motor resides in the Hunterian Museum in Glasgow, Scotland

Photo 4



Many thanks to Wikipedia for the above information and photos

This is a photo of the Baldor Reliance motor taken from their EFM4316T product Catalog. As you can see motors have indeed come a long way.

Photo 5

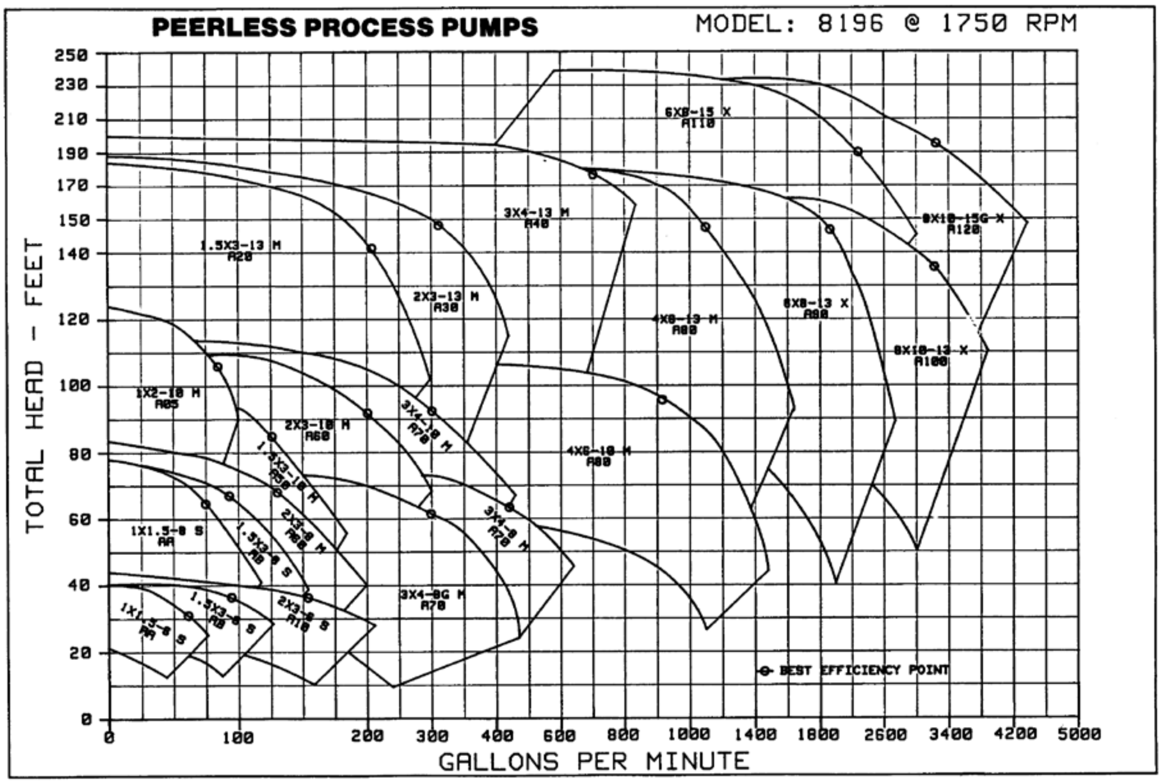
A standard efficiency 100 hp motor is approximately 90% efficient and the high-efficiency motor is approximately 95% efficient. Using the following assumptions we see that the payback period is just over two years and the rate of return is 38% for motor replacement.

Replace 100 hp Motor		**Do Nothing**	**New Motor**
Motor efficency		90%	95%
Cost of Motor at X cost of motor horsepower	$40		$3,876
Construction at X times cost of material	0.25		$969
Annual Maintenance @ 4% of equipment cost	4%	$155	$155
Total Project Cost			$4,845
Annual Property Tax @ 1% of Investment	1%	$48	$48
Annual Income Tax @2% of Investment	2%	$97	$97
Project Life in years	10		
Interest Rate for Project	14%		
Capital Recovery Factor (A/P, i, n)	0.1917		$929
Annual cost of Capital, operations, maintenance, tax, etc.		$300	$1,229
Total Annual Cost of energy only		$61,401	$58,169
Total Annual Cost of energy and investment		$61,701	$59,398
Annual savings			$2,303
Years to payback			2.10
Rate of return			38%

Table 7

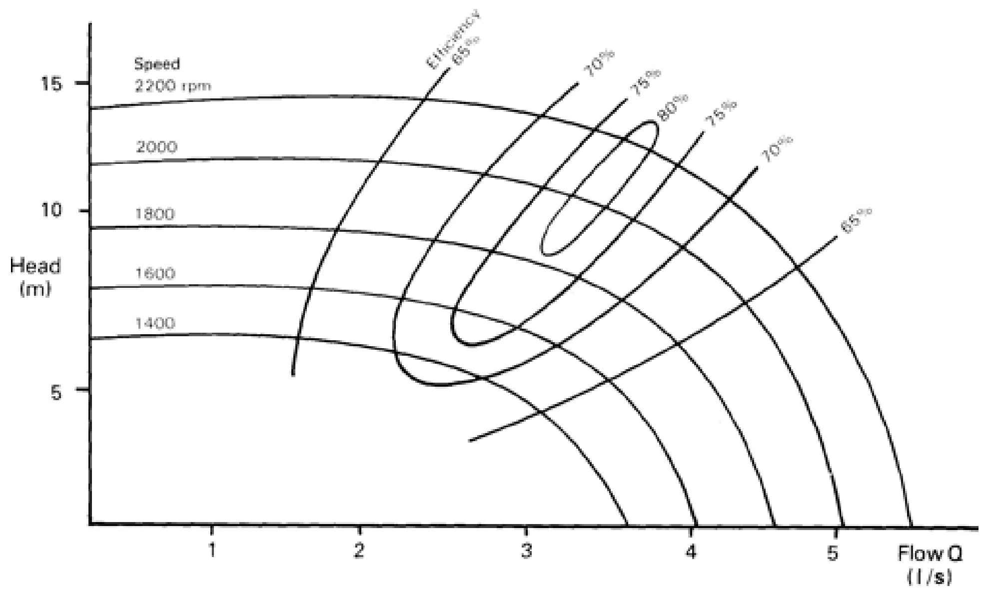
Pumps

Pumps handle a variety of fluids and are used for a wide array of flow rates and discharge pressures. The following chart from Peerless Process Pumps represents over 20 different size pumps that span flows of 25 to 5,000 GPM and total head of 20 to 250 feet. The important thing to notice is the best efficiency point, which is represented by the small θ symbol. For this pump efficiency example an engineer would select a pump from this chart that met the flow head requirements and then move to the specific pump curves.



Graph 5

The following pump curve provides an example of the islands of efficiency that in the previous chart were shown as single points. It's important for the engineer to select a pump such that the system curve and expected operating point is in the 80% efficiency island. A drop into the 75% area would cost the operating company extra money in energy cost as will be shown on the next page.



Graph 6

Variable Frequency Drives VFD) are excellent devices to replace energy wasting control valves; however they do not substitute for a properly selected pump. Moreover, as you see in this graph the reduction in flow and speed moves the operating point into a lesser efficiency area. If a pump is always operating at a reduced flow and head it might be time to perform some frequency analysis. Review the control system trended data and plot the actual flow to determine the hours of operation at each flow point and create a histogram. Then consult the pump curve and determine the actual operating pump efficiency compared to the best operating efficiency. This will provide the basis for an economic analysis to determine if a new pump will pay for itself.

The following table 8 shows the 41% rate of return that could be gained from improving from a 75% efficiency operating point to an 80% efficiency point for a constant speed pump.

Replace Constant speed 1,500 gpm at 100 feet of head			
Pump opperating efficency		75%	80%
Cost of Pump at X dollars per brake horsepower	$50		$5,216
Construction at X times cost of material	0.2		$1,043
Annual Maintenance @ 4% of equipment cost	4%	$209	$209
Total Project Cost			$6,259
Annual Property Tax @ 1% of Investment	1%	$63	$63
Annual Income Tax @2% of Investment	2%	$125	$125
Project Life in years	10		
Interest Rate for Project	14%		
Capital Recovery Factor (A/P, i, n)	0.191713541	$0	$1,200
Annual cost of Capital, operations, maintenance, tax, etc.		$396	$1,596
Total Annual Cost of energy only		$69,588	$65,238
Total Annual Cost of energy and investment		$69,984	$66,835
Annual savings			$3,149
Years to payback			1.99
Rate of return			41%
Table 8			

A VFD driven pump may well have an even better rate of return if it is always operating at reduced flow. Referring to the pump curve above and assuming that the flow is reduced by 25% the pump efficiency would fall from 80% to 70%. Improving this situation would yield an annual savings of almost $10,000 (see table 9 below) and depending on the investment required - i.e., new impeller, new pump, new pump and motor – could provide a one year payback.

Replace VFD Driven Pump 1,500 gpm at 100 feet of head			
Pump opperating efficency		70%	80%
Cost of Pump at X dollars per brake horsepower	$50		$5,589
Construction at X times cost of material	0.2		$1,118
Annual Maintenance @ 4% of equipment cost	4%	$224	$224
Total Project Cost			$6,706
Annual Property Tax @ 1% of Investment	1%	$67	$67
Annual Income Tax @2% of Investment	2%	$134	$134
Project Life in years	10		
Interest Rate for Project	14%		
Capital Recovery Factor (A/P, i, n)	0.191713541	$0	$1,286
Annual cost of Capital, operations, maintenance, tax, etc.		$425	$1,710
Total Annual Cost of energy only		$74,558	$65,238
Total Annual Cost of energy and investment		$74,983	$66,949
Annual savings			$8,034
Years to payback			0.83
Rate of return			117%
Table 9			

Power Factor Correction

Electric motors impose a large inductive load on the power supply that results in reactive power (kVAR) to sustain the magnetic field of the motor. The following power triangle will illustrate.

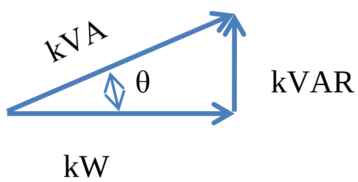


Figure 5

The kW is the actual working power,
kVA is what is being purchased, and
kVAR is the reactive power that is also sometimes purchased*.
Power Factor (PF) is kW/kVA = cosine θ

*The TECO GSD tariff sheet 6.081 20th revised sheet states in part….”Power Factor…is less than 85%, the monthly bill will be increased 0.222¢ for each kVARh by which the reactive energy…..

Reactive power can be corrected by installing capacitors in the circuit. The rate of return is very good and there are companies whose business model is to work with industry to purchase and install capacitors and then these energy service companies get paid based on electric bill savings.

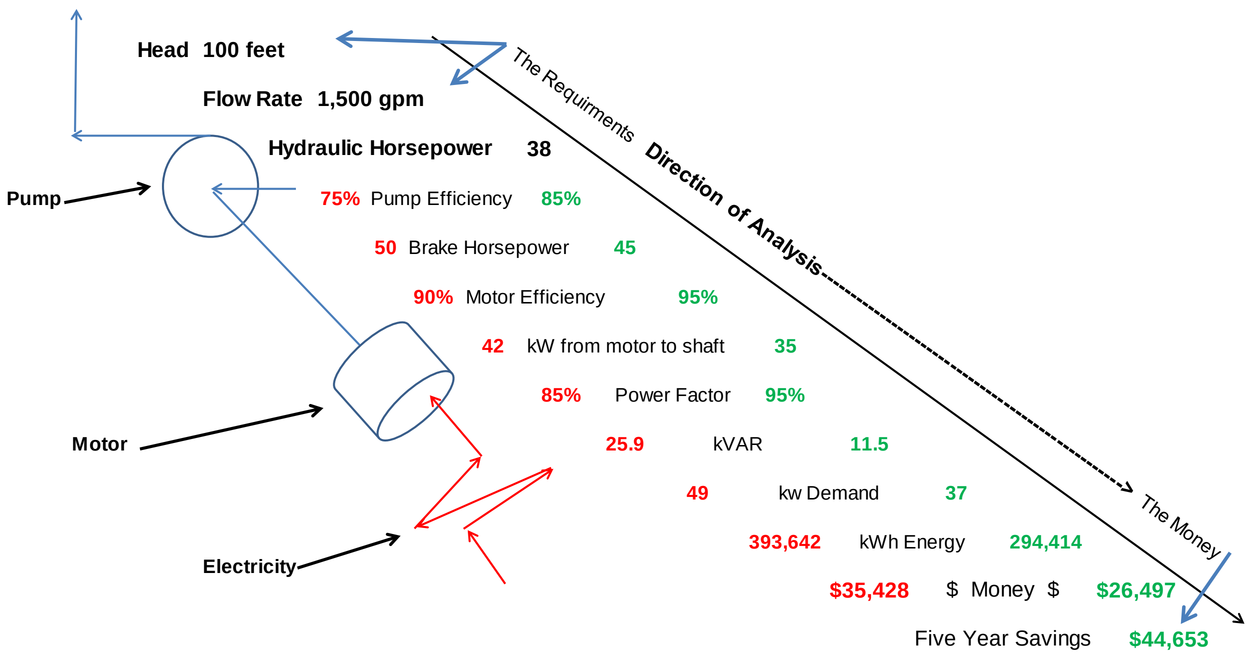
The following is an example of a 100 hp 480 volt three phase motor showing the savings from improving from a 90% to a 91% PF. Capacitors are inexpensive and this example pays back in less than half a year.

Install Power Factor Correction Capactor			
Power Factor		90%	91%
Cost of capacitor at X dollars per kVAR	$100		$233
Construction at X times cost of material	0.2		$47
Annual Maintenance @ 4% of equipment cost	4%	$183	$183
Total Project Cost			$279
Annual Property Tax @ 1% of Investment	1%	$3	$3
Annual Income Tax @2% of Investment	2%	$6	$6
Project Life in years	10		
Interest Rate for Project	14%		
Capital Recovery Factor (A/P, i, n)	0.191713541		$54
Annual cost of Capital, operations, maintenance, tax, etc.		$192	$245
Total Annual Cost of energy only		$65,983	$65,238
Total Annual Cost of energy and investment		$66,175	$65,483
Annual savings			$691
Years to payback			0.40
Rate of return			247%

Table 10

Let's return to the illustration of page 18 and fill in some of the values. The process requirement is a 1,500 gpm flow rate at 100 feet of head which is a hydraulic horsepower of 38 in the perfect world. However, as engineers we straddle the divide between perfect and reality and understand the laws of thermodynamics. Moreover, we strive to utilize the best available and cost effective equipment that can provide the results required; knowing that manufactures are improving on those inefficiencies of reality every day. With this as a backdrop let's consider the following red and green comparison of what might be actual installed equipment (red values on left side) with currently available equipment performance (green on right side) and take note of the financial bottom line.

Figure 6 Pump System Analysis Detailed



After all, at the end of the day our job – at the most basic level[6] – is to use material, money, and labor to build those things that society needs / wants / funds. We utilize our skills, schedules, plans, and budget to construct profit making facilities for the owners of the corporation.

There has been much focus on construction budgets with the idea that cheaper is better. However, sometimes cheap selections result in large and ongoing monthly operational costs. The figure above shows the string of inefficiencies that take a 38 horsepower need to either a $35,428 annual cost or a $26,497 annual cost. That results in an $8,931 annual savings or a five year $44,653 nominal savings. Go ahead, walk around the facility and look for those energy efficiency opportunities that on the surface seem small, yet yield large corporate savings.

[6] This is a loose paraphrase of the message from Mr. Hardy Cross's book "Engineers and Ivory Towers"

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Air conditioner condenser in side yard on page 9 by author

Name plate of air conditioner on page 11 by author

Anyos Jekik 1827 motor on page 18 compliments of Wikipedia

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