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Water/Wastewater Engineering Report

(High Efficiency Pump/Motor Replacement - M2 Model)

Report to the
Texas Commission on Environmental Quality

TCEQ

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Disclaimer

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Executive Summary

This report presents the methodology used to develop the high efficiency pump/motor model (M2) for wastewater treatment and water treatment plant. It reviews the engineering equations that were used to develop the model. It also includes a detailed description of an example to illustrate the methodology.

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INTRODUCTION

Pumping water or wastewater is the largest use of electricity for a municipal water supply or wastewater treatment plant. Increasing the overall efficiency of the pumping system can achieve significant energy savings. Overall pump system efficiency depends on the efficiency of the motor, the pump, and the design of the piping layout. The model developed in this document focuses on improvements mostly to the pumping system rather than a municipal piping system. Furthermore, this model primarily addresses electric motor-driven pumps, and does not include the pumps driven with gasoline or diesel engines.

There are many ways to increase the efficiency of a pump, including impeller trimming, pump speed changes, and parallel or series pumping. Pumping system efficiency improvements can also be made by increasing the efficiency of the motor or pump directly (PG&E 1997). Pump efficiency can be improved by replacing worn or damaged impellers or replacing the old pump with a new high-efficiency pump.

Improved motor efficiency can be accomplished by replacing a standard-efficiency motor with a high- or premium-efficiency motor. In this document a methodology for calculating the savings from high efficiency pump/motor replacement (i.e., the "M2 model") is presented. This document provides a review of the engineering equations used for the pump system, a description of the M2 model, and an example to illustrate the methodology.

DESCRIPTION OF M2 MODEL

The intention of M2 model is to calculate the energy savings and NOx emissions reduction from high efficiency pump/motor replacement. As shown in Figure 1, the user is first required to enter the general information about the old pump and motor including motor HP, motor nominal efficiency, rated pump capacity, and total dynamic head. Then the user can choose from one of the three screens (screen 2A, 2B or 2C) to input the flow rate, motor power/head, old pump and new pump efficiencies, % of operating hours annually and in Ozone Season Day (OSD) period for a maximum of five periods. The user is also required to input the motor efficiencies for the same periods if they want to replace the old motor with premium efficiency motor. Based on the above input, the ESL's emissions calculator (eCalc) calculates the electricity savings from the pump/motor replacement. In the output report, the annual electricity savings (kWh/yr), OSD electricity savings (kWh/day), and emissions reductions in 1999, 2002, 2007 and 2010 for annual and OSD periods are provided. The model also addresses growth rates from 1999 or 2002 to the year of the retrofit, and from the year from the retrofit to 2007 and 2010.

For this analysis, the 2007-annual eGRID, developed by the EPA especially for Texas, was used to predict the annual 2007 pollution for utilities in the ERCOT Power Control Area. The 2007-OSD eGRID was used for calculating the daily emissions on Ozone Season Days. Both the annual and OSD calculations assume eGRID's 25% plant capacity factor. In eGRID the NOx production for each power plant is provided for ten electric utility suppliers (i.e., AEP, Austin Energy, Brownsville Public Utility, LCRA, Reliant, San Antonio Public Service, South Texas Coop, TMPP, TNMP, and TXU). In the case of an unknown power provider, the M2 model assigns the utility based on the PUC's 2002 Power Control Authority (PCA) listing[1]. Once the utility provider had been chosen for a given county the eGRID emission factor for 2007 is used for both 2007 and 2010 calculations.

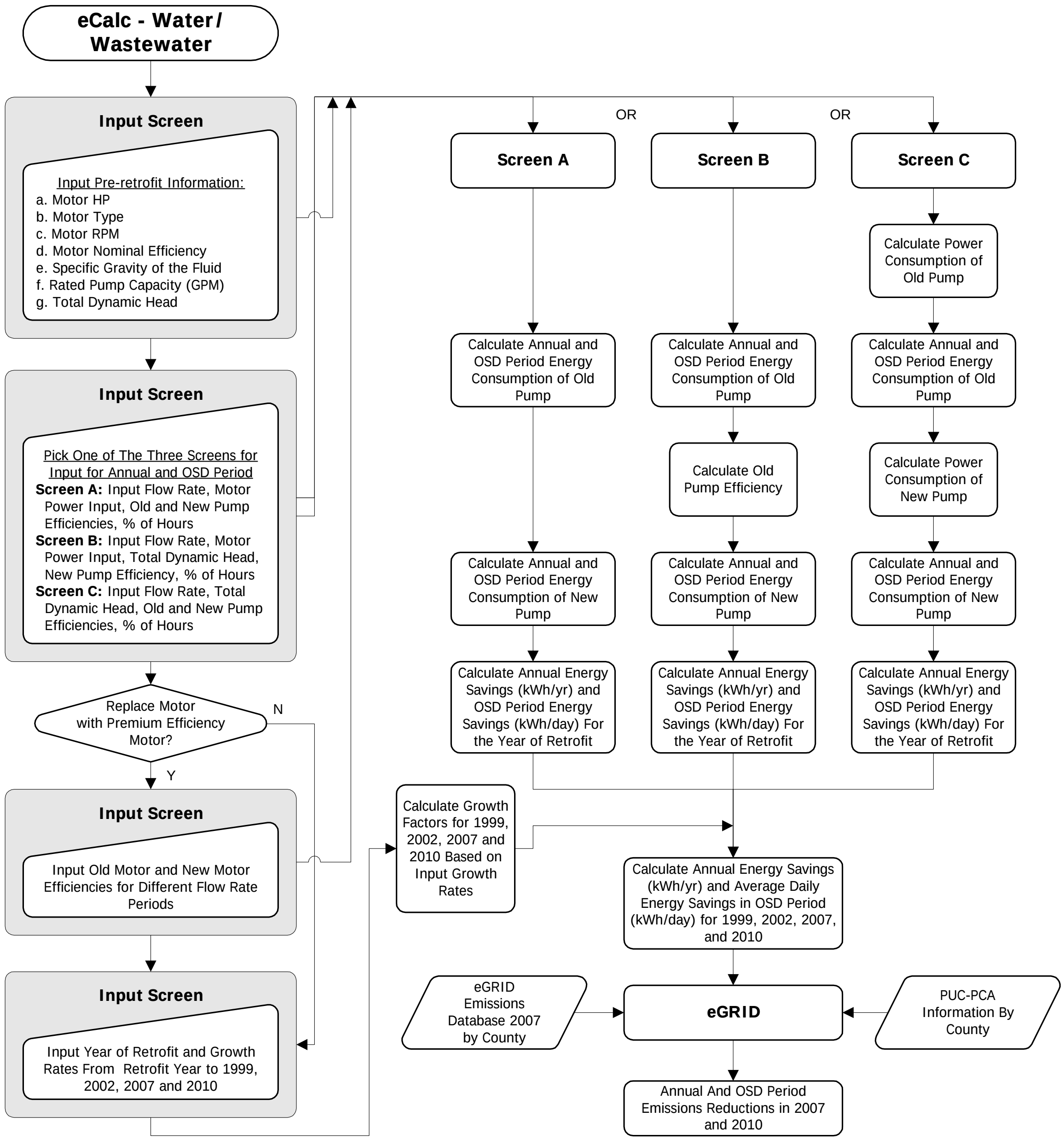

Figure 1. Flow Chart for M2 Model.

[1] For more information on the assumptions behind this assignment see the ESL's 2004 Annual Report to the TCEQ (Haberl et al. 2004a, b, c).

ENGINEERING EQUATIONS FOR PUMP SYSTEM

A pump converts mechanical energy into pressurized fluid motion to move liquids through a piping network. In a centrifugal pump, an electric motor or other power source rotates the impeller at the motor's rated speed (constant speed pump), or at variable speeds (variable speed drives). Impeller rotation adds energy to fluid that enters the center or eye of the rotating impeller. The fluid is then acted upon by centrifugal force of the impellor, or tip speed force. These forces result in an increase in the pressure and velocity of the fluid. The pump casing is designed for the maximum conversion of velocity energy of the fluid into pressure energy, either by the uniformly increasing area of the volute or by diffuser guide vanes, when provided (ASHRAE 2001).

System Curves

Figure 2 depicts a typical pumping system head curve, or system curve. The three components of total system head are static head, design working head, and friction head. Static head is the vertical difference between the system's point of entry and its highest point of discharge. Design working head is that head that must be available at a specified location to satisfy design requirements. Friction head is the head required by the system to overcome the resistance to flow in pipes, valves, fittings and mechanical equipment.

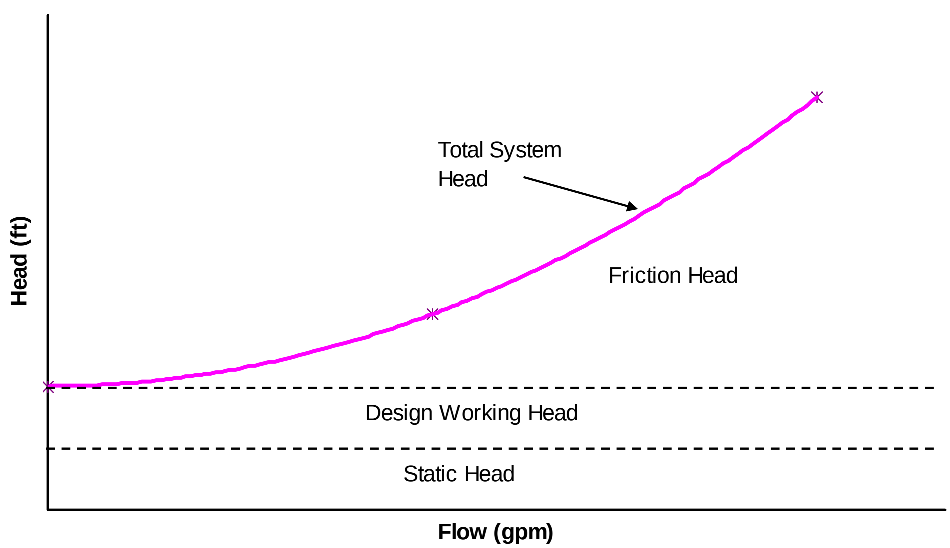

Figure 2. Pump System Curve.

Pump Curves

Pump manufacturers provide pump head-capacity curves, or pump curves, that predict pump performance, often shown as a single-line curve depicting one impeller diameter or as multiple curves for the performance of several impeller diameters in one casting. A pump operates over a range of pressure or head and flows for a given speed and impeller diameter. Change either the pressure or flow and a given pump will operate on a different curve. One characteristic of centrifugal pumps is that, for any given speed, as flow through the pump increases, its head decreases. The pump design point is the point on the curve where maximum efficiency is attained.

A system curve can be developed and overlaid on the pump curve. The system curve represents how the piping network responds to varying flow and pressure. The intersection of the pump head-capacity curve and the system curve represents the operating point of the pump for a specific piping system (Figure 3). This condition represents the point at which pump head matches the system head as defined by the system piping configuration.

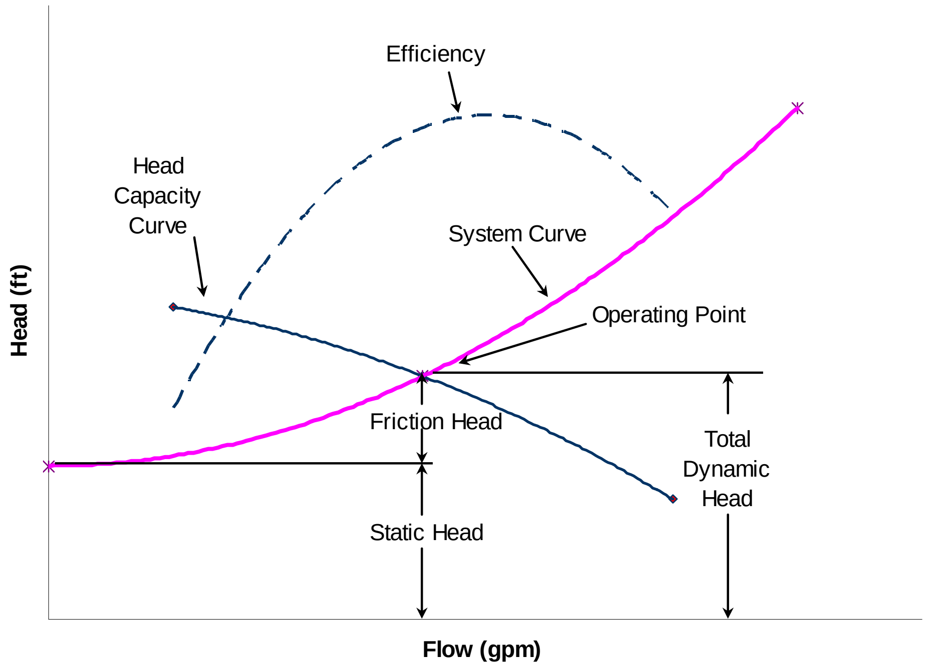

Figure 3. System Curve and Pump Curve.

<u>Pump Power and Efficiency</u>

The following two equations can be used to determine pumping power (ASHRAE 2001):

Water Horsepower [2] *= Mass Flow of Fluid (lb/min) x Total Head (ft) / 33,000* (1)

At 68 F, water has a density of 62.3 lb/ft^3, and equation (1) becomes

Water Horsepower [3] *= Fluid Flow Rate (gpm) x Total Head (ft) / 3,960* (2)

[2] The theoretical power to circulate water in a hydronic system is the water horsepower (whp). 33,000 in the equation converts ft-lb/min to hp.
[3] In this equation, 3960 converts ft-gal/min to hp.

For other fluids, equation (3) can be used to determine the water horsepower (Bolles et al. 2005, Dickenson 1995, PG&E 1997, McQuiston et al. 1994):

Water Horsepower = Fluid Flow Rate (gpm) x Total Head (ft) x Specific Gravity of the Fluid/ 3,960 *(3)*

Pump efficiency is determined by comparing the pump fluid output power to the pump input power (ASHRAE 2001):

Pump Efficiency = Output / Input = Water Horsepower (hp) x 100% / Brake Horsepower (hp) *(4)*

Motor efficiency measures how effectively the motor turns electrical energy into mechanical energy and is determined by the following equation for a pumping system:

Motor Efficiency = Output / Input = Brake Horsepower (hp) x 100% / Motor Input (hp) *(5)*

Therefore, by applying equations (3) and (4) into (5), the pumping system electric power can be calculated as follows:

Motor Power Input (kW) = Fluid Flow Rate (gpm) x Total Head (ft) x Specific Gravity of the Fluid/ (5,310 x Motor Efficiency x Pump Efficiency) *(6)*

<u>Affinity Laws</u>

The centrifugal pump, which imparts a velocity to a fluid through the impellor, and converts the velocity energy to pressure energy, can be categorized by a set of relationships called affinity laws (Table 1). These laws can be described by the following Rules (ASHRAE 2001):

1. Flow (capacity) varies with rotating speed N (i.e., the peripheral velocity of the impeller).
2. Head varies as the square of the rotating speed.
3. Brake horsepower varies as the cube of the rotating speed.

The affinity laws are useful for estimating pump performance at different rotating speeds or impeller diameters based on a pump with known characteristics.

Table 1. Pump Affinity Laws.

Function	Speed (N) Change	Impeller Diameter (D) Change
Flow (Q)	$Q_2 = Q_1(N_2/N_1)$	$Q_2 = Q_1(D_2/D_1)$
Head (h)	$h_2 = h_1(N_2/N_1)^2$	$h_2 = h_1(D_2/D_1)^2$

Horsepower (bhp)	$bhp_2 = bhp_1(N_2/N_1)^3$	$bhp_2 = bhp_1 (D_2/D_1)^3$

Energy Savings Calculations

When improvements are made in motor or pump efficiency, the following standard calculations can be used to estimate energy savings (PG&E 1997):

Motor Efficiency Improvement:

kWh Savings = Brake Horsepower (hp) x 0.7457 (kW/hp) x (1/Old Motor Efficiency – 1/New Motor Efficiency) x Operating Hours (hrs) *(7)*

Pump Efficiency Improvement:

kWh Savings = Brake Horsepower of Old Pump x 0.7457 (kW/hp) x (1 – Old Pump Efficiency / New Pump Efficiency) x Operating Hours (hrs) *(8)*

Improve Motor or Pump Efficiency

Pump system efficiency or motor efficiency can be improved directly by increasing the efficiency of the motor and/or pump. The following actions are most often taken to improve pump/motor efficiency (PG&E 1997):

- *High-Efficiency Motors:* A 3 to 5 percent increase in the motor efficiency of a high- or premium-efficiency motor can provide quick paybacks.

- *Replacing or Repairing the Pump Impeller and/or the Pump Bowl:* A retrofit of the impeller and bowl assembly of a pumping system, and the optimal placement of the pump bowls relative to water levels, can improve pump system efficiency.

- *Pump Adjustment:* Proper adjustment of the impeller relative to the bowl assembly will minimize the clearance between impeller and bowl and maximize the quantity of water pumped.

- *High-Efficiency Pumps:* Replacement of an old, worn pump with a new high-efficiency pump can improve the pump system efficiency.

The potential for improving the efficiency of a pumping plant is highly dependent on the age and design of the equipment and its operation. An old, worn pump and standard-efficiency motor may be operating in the vicinity of 50 percent efficiency. A new pump and premium-efficiency motor can improve overall pump efficiency to over 60 percent, a 10 percent or more improvement (PG&E 1997).

EXAMPLE APPLICATION OF THE M2 MODEL

In this section, a step-by-step example is given to illustrate the methodology used in the M2 model.

1. User Input

First the user enters the old motor and pump information including the horsepower, type, RPM, and nominal efficiency of motor, specific gravity of the fluid, rated pump capacity, and total dynamic head as shown in Figure 4.

Next, the user needs to select one of three screens (2A, 2B, or 2C) to enter the necessary information for calculating the energy savings for a maximum of five flow-duration periods annually, and in the OSD period depending on the availability of the information, as shown in the first block of Figure 5. If the user is using screen 2A, they need input Flow Rate, Motor Power Input, Old Pump Efficiency and New Pump Efficiency for each period[4]. If using screen 2B, the user needs to input Flow Rate, Motor Power Input, Total Dynamic Head, and New Pump Efficiency for each period. If using screen 2C, the user needs to input Flow Rate, Total Dynamic Head, Old Pump Efficiency and New Pump Efficiency for each period. The second block of Figure 5 presents an example of the input for all the three input screens.

Next, the user inputs the efficiency of the old motor and new motor if it is decided to replace the old standard-efficiency motor with a high- or premium-efficiency motor (Figure 6). The default nominal efficiencies for NEMA Premium induction motors are provided in the input screen for the new motors (NEMA 2005).

Finally, as shown in Figure 7, the user provides the year of the retrofit and the anticipated growth of their system covering 1999 or 2002 to the current period and from the current period to 2007 and 2010. In this example, the user inputs the growth rates from 1999 and 2002 to 2005 and from 2005 to 2007 and 2010. This allows the calculations to evaluate the conditions in the base year (i.e., 1999 or 2002), and in the 2007 and 2010 future years, given the current year of 2005.

1. Customer: Input Pre-retrofit Information

1a	Motor HP (hp)	60
1b	Motor Type	Enclosed
1c	Motor RPM	1800
1d	Motor Nominal Efficiency	0.92
1e	Specific Gravity of the Fluid	1.00
1f	Rated Pump Capacity (GPM)	3500
1g	Rated Head (ft)	50

Note: GPM means gallon per minute.

Figure 4. User Input Requirement-1.

[4] The M2 model assumes the year or OSD can be divided into 5 periods that represent the operation of the pump. The user is then required to supply the needed information for each of these periods.

2. Customer: Select One of the Three Input Screens

2A Input: Flow Rate, Motor Power Input, Old Pump Efficiency and New Pump Efficiency. Calculator then calculates savings.
2B Input: Flow Rate, Motor Power Input, Total Dynamic Head, and New Pump Efficiency. Calculator first calculates Old Pump Efficiency, then calculates savings.
2C Input: Flow Rate, Total Dynamic Head, Old Pump Efficiency and New Pump Efficiency. Calculator first calculates energy use of new pump, then calculates savings.

Explaination of Terms:

Total Dynamic Head:	Head is a measure of the pressure or force exerted by the fluid. Total Dynamic head is the addition of Static Lift, Static Height, and Friction Loss.
Motor Power Input:	The electrical input to the motor expressed in kilowatts (kW). A measure of the rate at which work is done.
Pump Efficiency:	The ratio of the energy delivered by the pump to the energy supplied to the pump shaft.
Motor Efficiency:	A measure of how effectively the motor turns electrical energy into mechanical energy. It is the ratio of power input to power output.

Screen 2A. Customer: Input Pre and Post Retrofit Information

Customer estimates the percent of time annually the pump is operating at different flow rates and motor power input, old pump and new pump efficiencies at different flow rates.

Period No.	Flow Rate (GPM) [2a]	% of Hours Per Year Pump is Operating at this Flow Rate [2b]	Motor Power Input (kW) [2c]	Old Pump Efficiency [2d]	New Pump Efficiency [2e]
1	3000	50%	42.30	70%	80%
2	2000	20%	12.92	70%	80%
3	1000	20%	5.00	70%	80%
4	0	10%	-	-	-
5					
Total		100%			

Customer estimates the percent of time the pump is operating at different flow rates and motor power input, old pump and new pump efficiencies at different flow rates for OSD period (Jul 15 through Sep 15).

Period No.	Flow Rate (GPM) [2f]	% of Hours Pump is Operating at this Flow Rate [2g]	Motor Power Input (kW) [2h]	Old Pump Efficiency [2i]	New Pump Efficiency [2j]
1	3000	40%	42.30	70%	80%
2	2000	20%	12.92	70%	80%
3	1000	30%	5.00	70%	80%
4	0	10%	-	-	-
5					
Total		100%			

Screen 2B. Customer: Input Pre and Post Retrofit Information

Customer estimates the percent of time annually the pump is operating at different flow rates and motor power input, total dynamic head, and new pump efficiencies at different flow rates.

Period No.	Flow Rate (GPM) [2a]	% of Hours Per Year Pump is Operating at this Flow Rate [2b]	Motor Power Input (kW) [2c]	Total Dynamic Head (Ft) [2d]	New Pump Efficiency [2e]
1	3000	50%	42.30	50	80%
2	2000	20%	12.92	22	80%
3	1000	20%	5.00	15	80%
4	0	10%	-	-	-
5					
Total		100%			

Customer estimates the percent of time the pump is operating at different flow rates and motor power input, total dynamic head, and new pump efficiencies at different flow rates for OSD period (Jul 15 through Sep 15).

Period No.	Flow Rate (GPM) [2f]	% of Hours Pump is Operating at this Flow Rate [2g]	Motor Power Input (kW) [2h]	Total Dynamic Head (Ft) [2i]	New Pump Efficiency [2j]
1	3000	40%	42.30	50	80%
2	2000	20%	12.92	22	80%
3	1000	30%	5.00	15	80%
4	0	10%	-	-	-
5					
Total		100%			

Screen 2C. Customer: Input Pre and Post Retrofit Information

Customer estimates the percent of time annually the pump is operating at different flow rates and total dynamic head, old pump efficiency, and new pump efficiency at different flow rates.

Period No.	Flow Rate (GPM) [2a]	% of Hours Per Year Pump is Operating at this Flow Rate [2b]	Total Dynamic Head (ft) [2c]	Old Pump Efficiency [2d]	New Pump Efficiency [2e]
1	3000	50%	50	70%	80%
2	2000	20%	22	70%	75%
3	1000	20%	15	70%	70%
4	0	10%	-	-	-
5					
Total		100%			

Customer estimates the percent of time the pump is operating at different flow rates and total dynamic head, old pump efficiency, and new pump efficiencies at different flow rates for OSD period (Jul 15 through Sep 15).

Period No.	Flow Rate (GPM) [2f]	% of Hours Pump is Operating at this Flow Rate [2g]	Total Dynamic Head (ft) [2h]	Old Pump Efficiency [2i]	New Pump Efficiency [2j]
1	3000	40%	50	70%	80%
2	2000	20%	22	70%	75%
3	1000	30%	15	70%	70%
4	0	10%	-	-	-
5					
Total		100%			

Figure 5. User Input Requirement-2.

3. Customer: Chooses if they Want to Replace Exisiting Motor with Premium Efficient Motor or Not.

If the answer is YES, Customer need to input motor efficiency in the following screen.

Period No.	Old Motor Efficiency [3a]	New Motor Efficiency [3b]
1	92%	96%
2	92%	96%
3	92%	96%
4	-	-
5		

If the answer if NO, the above screen is not shown for customer but Nominal Efficiency Number (1b) is saved in the corresponding cells of this table (3a and 3b) for the later calcualtion.
Note: Default value will be given according to the motor HP input by customer in Step 1 and the database on Motor Efficiency Information.

Figure 6. User Input Requirement-3.

4. Customer: Input Growth Rate

Note: The following growth rates are applied equally to each of the (5) flow duration periods (excluding periods with zero flow).
This is equivalent to multiplying the total savings times the total growth rate (annual and OSD).

Input the Year of the Retrofit

4a	Year of Retrofit	2005

If the year of retrofit is after Dec. 31, 2002, use Screen 4A for input

Screen 4A:

4b	Total Growth Rate From 1999 to Current Period	20%
4c	Total Growth Rate From 2002 to Current Period	10%
4d	Total Projected Growth From Current Period to 2007	15%
4e	Total Projected Growth From Current Period to 2010	30%

If the year of retrofit is between Jan. 01, 1999 to Dec. 31, 2002, use Screen 4B for input

Screen 4B:

4b	Total Growth Rate From 1999 to Current Period	10%
4c	Total Growth Rate From current period to 2002	10%
4d	Total Projected Growth From Current Period to 2007	30%
4e	Total Projected Growth From Current Period to 2010	45%

Note: 1999 and 2000 mean 1/1/1999 and 12/31/2002 respectively.

Figure 7. User Input Requirement-4.

2. Calculate the Energy Consumption of Old Pump

Next, the energy consumption of the old pump is calculated. First, the number of hours for the retrofit year and the OSD period are calculated. Then, depending on which method the user has chosen, different methods are used for the information provided by screens 2A, 2B, or 2C to calculate the energy consumption (Figure 8).

For example, using input from screen 2A, the measured motor input for each period was provided by the user. The following equation was used to calculate the energy consumption of the old pump:

kWh of Pump (kWh) = Motor Power Input (kW) x % of Hours Pump is Running x No. Of Hours Per Year or in OSD Period *(9)*

Using input from screen 2B, assuming the displayed motor input power, equation (9) is used to calculate the energy consumption of the old pump.

5a	No of Hours in Retrofit Year (hrs/yr):	8760
5b	No of Hours in OSD Period -Jul. 15 to Sep. 15 (hrs):	1488

Annual

	Screen 2A	Screen 2B	Screen 2C	
Period No.	Energy Consumption of Old Pump (kWh/yr) [5c=2b*2c*5a]	Energy Consumption of Old Pump (kWh/yr) [5c=2b*2c*5a]	Calcualted kW of Old Pump (kW) [5d=2a*2c*1e/ (5310*2d*3a)]	Energy Consumption of Old Pump (kWh/yr) [5c=5d*2b*5a]
1	185,274	185,274	43.86	192,125
2	22,638	22,638	12.87	22,543
3	8,760	8,760	4.39	7,685
4	0	0	0.00	0
5				
Total [$5c_{sum}$]	**216,672**	**216,672**		**222,353**

OSD-Jul 15 to Sep 15

	Screen 2A	Screen 2B	Screen 2C	
Period No.	Energy Consumption of Old Pump (kWh) [5e=2g*2h*5b]	Energy Consumption of Old Pump (kWh) [5e=2g*2h*5b]	Calculated kW of Old Pump (kW) [5f=2f*2h*1e/ (5310*2i*3a)]	Energy Consumption of Old Pump (kWh) [5e=5f*2g*5b]
1	25,177	25,177	43.86	26,108
2	3,845	3,845	12.87	3,829
3	2,232	2,232	4.39	1,958
4	0	0	0.00	0
5				
Total [$5e_{sum}$]	**31,254**	**31,254**		**31,895**

		Screen 2A	Screen 2B	Screen 2C
5g	Annual Energy Consumption of Old Pump [kWh/yr] =	216,672	216,672	222,353
5h	Energy Consumption of Old Pump In OSD Period [kWh] =	31,254	31,254	31,895

Figure 8. Calculation of Energy Consumption of Old Pump.

Using input from screen 2C, which includes the total dynamic head, equation (6) is used to calculate the old motor power input. Then equation (9) is used to calculate the energy consumption of the old pump.

3. Calculate the Energy Consumption of the New Pump

As shown in Figure 9, the calculation of energy consumption of the new pump is different for the different input screens, 2A, 2B, or 2C.

For screen 2A, the following equation is used to calculate the energy consumption of the new pump:

kWh of the New Pump (kWh) = Brake Horsepower of the New Pump (hp) x 0.7457 kW/hp x % of Hours Pump is Running x No. of Hours per Year or in OSD Period (hrs) / New Motor Efficiency *(10)*

The brake horsepower of the new pump can be obtained using the following equation:

Brake Horsepower of the New Pump (hp) = Brake Horsepower of the Old Pump (hp) x Old Pump Efficiency / New Pump Efficiency = Old Motor Power Input (kW) x Old Motor Efficiency x Old Pump Efficiency / (New Pump Efficiency x 0.7457 kW/hp) *(11)*

Annual

Period No.	Screen 2A: Energy Consumption of New Pump (kWh/yr) [6a=3a*2b*2c*2d*5a/(2e*3b)]	Screen 2B: Old Pump Efficiency [6b=2a*2d*1e/(5310*2c*3a)]	Screen 2B: Energy Consumption of New Pump (kWh/yr) [6a=3a*2b*2c*5c*6b/(2e*3b)]	Screen 2C: Calculated kW of New Pump [6c=2a*2c*1e/(5310*2e*3b)]	Screen 2C: Energy Consumption of New Pump (kWh/yr) [6a=6c*2b*5a]
1	155,360	0.73	161,105	36.78	161,105
2	18,983	0.70	18,903	11.51	20,163
3	7,346	0.61	6,444	4.20	7,365
4	0	-	0	0.00	0
5					
Total [$6a_{sum}$]	**181,688**		**186,452**		**188,633**

OSD-Jul 15 to Sep 15

Period No.	Screen 2A: Energy Consumption of New Pump (kWh) [6d=3a*2g*2h*2i*5b/(2j*3b)]	Screen 2B: Old Pump Efficiency [6e=2f*2i*1e/(5310*2h*3a)]	Screen 2B: Energy Consumption of New Pump (kWh) [6d=3a*2g*2h*6e*5b/(2j*3b)]	Screen 2C: Calculated kW of New Pump [6f=2f*2h*1e/(5310*2j*3b)]	Screen 2C: Energy Consumption of New Pump (kWh) [6d=2g*6f*5b]
1	21,112	0.73	21,893	36.78	21,893
2	3,224	0.70	3,211	11.51	3,425
3	1,872	0.61	1,642	4.20	1,877
4	0	-	0	0.00	0
5					
Total [$6d_{sum}$]	**26,208**		**26,746**		**27,194**

		Screen 2A	Screen 2B	Screen 2C
6g	Annual Energy Consumption of New Pump [kWh/yr] =	181,688	186,452	188,633
6h	Energy Consumption of New Pump In OSD Period [kWh] =	26,208	26,746	27,194

Figure 9. Calculation of Energy Consumption of New Pump.

By combining equations (10) and (11), the equation (12) is obtained and used to calculate the energy consumption of the new pump. The results are shown in Figure 9.

kWh of the New Pump (kWh) = Old Motor Power Input (kW) x Old Motor Efficiency x Old Pump Efficiency x % of Hours Pump is Running x No. Of Hours Per Year or in OSD Period (hrs) / (New Pump Efficiency x New Motor Efficiency) *(12)*

For screen 2B, first the old pump efficiency is calculated using equation (6). Then, the energy consumption of the new pump is calculated using equation (12).

For screen 2C, first the motor power input is calculated using equation (6). Then, the energy consumption of the new pump is calculated through equation (9).

4. Calculate Annual Energy Savings and Energy Savings in OSD Period (Jul 15 through Sep 15).

In this step, the annual and OSD energy savings are calculated by comparing the energy consumption of old pump to the energy consumption of new pump, as shown in Table **2** for each of the screen input methods 2A, 2B, and 2C.

Table 2. Calculation of Energy Savings.

		Screen 2A	Screen 2B	Screen 2C
7a	Annual Energy Savings [kWh/yr] =	**34,983**	**30,219**	**33,720**
7b	Average Daily Energy Savings in OSD Period [kWh/day]=	**81.39**	**72.72**	**75.82**

5. Calculate Growth Factor for 1999, 2002, 2007 and 2010

To project the annual and OSD savings for 2007 and 2010, first the growth factor from the year of retrofit to 2007 and 2010 need to be calculated according to the input in Screen 4A or 4B shown in Figure 7. If the retrofit is after December 31, 2002, the first table in Table 3 is used to calculate the growth factor. If the retrofit happens between January 1, 1999 and December 31, 2002, the second table in Table 3 is used to calculate the growth factor. The growth from 1999 and 2002 to the year of retrofit is also calculated and listed in these two tables.

Table 3. Calculation of Growth Factor.

	Calculated Growth Factor
1999 [8a=1/(1+4b)]	83%
2002 [8b=1/(1+4c)]	91%
2007 [8c=1+4d]	115%
2010 [8d=1+4e]	130%

	Calculated Growth Factor
1999 [8a=1/(1+4b)]	91%
2002 [8b=1+4c]	110%
2007 [8c=1+4d]	130%
2010 [8d=1+4e]	145%

6. Calculate 1999, 2002, 2007 and 2010 Annual Energy Savings and Energy Savings in OSD Period

Next, the annual and average OSD electricity savings are calculated based on the savings in the year of retrofit and growth factors from the year of retrofit to 2007 and 2010. The first table in Table 4 shows the projected electricity savings in 2007 and 2010 and the savings backward to 1999 and 2002 if the year of retrofit is after December 31, 2002. The second table in Table 4 shows the projected electricity savings in 2007 and 2010 and the savings backward to 1999 and 2002 if the year of retrofit is between January 1, 1999 and December 31, 2002.

7. Emissions Reduction in 2007 and 2010

Finally, in the next step the USEPA's eGRID database is used to project annual and average daily OSD period NOx, SOx, and CO2 reductions in 1999, 2002, 2007, and 2010. Table 5 shows an example of the emissions reduction report that will be sent to the user[5].

[5] The values shown in Table 5 are for illustration only. The M2 model will calculate these values with the 2007 eGRID and 2007-OSD eGRID for the specific utility provider chosen or assigned to the project.

Table 4. Energy Savings in 1999, 2002, 2007 and 2010.

Screen 4A: The year of retrofit is after Dec. 31, 2002

1999	Screen 2A	Screen 2B	Screen 2C
Annual Energy Savings [kWh/yr] =	29,153	25,183	28,100
Average Daily Energy Savings in OSD Period [kWh/day]=	67.83	60.60	63.19

2002	Screen 2A	Screen 2B	Screen 2C
Annual Energy Savings [kWh/yr] =	31,803	27,472	30,655
Average Daily Energy Savings in OSD Period [kWh/day]=	73.99	66.11	68.93

2007	Screen 2A	Screen 2B	Screen 2C
Annual Energy Savings [kWh/yr] =	40,231	34,752	38,778
Average Daily Energy Savings in OSD Period [kWh/day]=	93.60	83.63	87.20

2010	Screen 2A	Screen 2B	Screen 2C
Annual Energy Savings [kWh/yr] =	45,478	39,285	43,836
Average Daily Energy Savings in OSD Period [kWh/day]=	105.81	94.54	98.57

Screen 4B: The year of retrofit is between Jan. 01, 1999 to Dec. 31, 2002

1999	Screen 2A	Screen 2B	Screen 2C
Annual Energy Savings [kWh/yr] =	31,803	27,472	30,655
Average Daily Energy Savings in OSD Period [kWh/day]=	73.99	66.11	68.93

2002	Screen 2A	Screen 2B	Screen 2C
Annual Energy Savings [kWh/yr] =	38,482	33,241	37,092
Average Daily Energy Savings in OSD Period [kWh/day]=	89.53	79.99	83.41

2007	Screen 2A	Screen 2B	Screen 2C
Annual Energy Savings [kWh/yr] =	45,478	39,285	43,836
Average Daily Energy Savings in OSD Period [kWh/day]=	105.81	94.54	98.57

2010	Screen 2A	Screen 2B	Screen 2C
Annual Energy Savings [kWh/yr] =	50,726	43,818	48,894
Average Daily Energy Savings in OSD Period [kWh/day]=	118.02	105.45	109.95

Table 5. Emissions Reduction Report.

Project ID	406
Job ID	146
County	BASTROP
Project Name	Mockup 2
Project POC EMail	dgilman@tamu.edu
Project Type	M2 - Pump Efficiency

1: ANNUAL SAVINGS

1.1: Energy Consumption	1999 Electricity (kWh/yr)	2002 Electricity (kWh/yr)	2007 Electricity (kWh/yr)	2010 Electricity (kWh/yr)
Electrical	154,884	170,372	187,410	206,151

1.2 Emissions By Type	1999 Emissions (lbs/yr)	2002 Emissions (lbs/yr)	2007 Emissions (lbs/yr)	2010 Emissions (lbs/yr)
NOx	2.00	1.84	1.69	1.56
SOx	14.00	12.88	11.85	10.90
CO2	1,425.00	1,311.00	1,206.12	1,109.63

2: TYPICAL OSD SAVINGS

2.1: Energy Consumption	1999 Electricity (kWh/day)	2002 Electricity (kWh/day)	2007 Electricity (kWh/day)	2010 Electricity (kWh/day)
Electrical	154,884	170,372	187,410	206,151

2.2 Emissions By Type	1999 Emissions (lbs/day)	2002 Emissions (lbs/day)	2007 Emissions (lbs/day)	2010 Emissions (lbs/day)
NOx	2.00	1.84	1.69	1.56
SOx	14.00	12.88	11.85	10.90
CO2	1,425.00	1,311.00	1,206.12	1,109.63

SUMMARY

This report has presented the methodology used to develop the high-efficiency pump/motor model (M2) for a wastewater treatment and water treatment plant. It reviewed the engineering equations that were used to develop the models, and includes a detailed example of the application of the model.

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